An Ecological Survey

of the

BabbittPeak Candidate Research Natural Area

on the

Tahoe National Forest

Order No. 1222-PSW-75

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INTRODUCTION

Babbitt Peak Candidate Research Natural Area encompasses 707 ha about the crest of the Bald Mountain Range (northeastern Sierra Nevada). It is situated along the east boundary of Tahoe and west boundary of Toiyabe National Forest in Sierra County, California and extends 4.04 km north-south between 39° 35' and 39° 37.5' N Latitude and from 120° 5' to 120° 7' Longitude (Figure 1). Watersheds within this area drain to the west as part of the uppermost tributaries of the Feather River. Babbitt Peak, the highest point in the Bald Mountain Range (2,670 m), lies along the east-central boundary of the proposed natural area.

The main ridge of the Bald Mountain Range runs northwest to southeast. About the central ridge topography consists of gentle convex or concave slopes interrupted by occasional rock outcrops. West and east facing slopes become strongly convex further from this central ridge. Two lateral extensions (spur ridges) extend from the central ridge within the study area (Figure 1). One spur ridge runs 1.6 km to the northeast before elevations below 2,380 m (about 7,800 ft) are encountered. Another lateral extension occurs in the southwest corner of the proposed natural area.

Vegetative features include both scrub and coniferous forest cover types. High elevation sagebrush scrub predominates on exposed south and west facing slopes and along ridge crests. Pine forests occur on gently sloping north and on

less exposed south, west, and east aspects, while true fir forests are dominant on steep north aspects and middle to lower slopes of canyons. Upper slopes of lateral ridges possess unique stands of Washoe pine and western white pine. This study provides a general ecological description of vegetation within the proposed Babbitt Peak Natural Area emphasizing composition, growth rates, and structure of coniferous vegetation.

PROCEDURE

Vegetation was field mapped according to dominant species and results transcribed onto an enlarged 15 minute series U.S. Geological Survey topographic sheet for Loyalton. Sites believed representative of forest vegetation within this region were subsequently analysed using 75 x 100 ft plots (0.07 ha) with the long axis parallel to slope direction (see Figure 1 for plot distribution). Woody and herbaceous vegetation was evaluated at each site using tabular comparison of Braun-Blanquet (Mueller-Dombois and Ellenberg, 1974). Arboreal species 2.54 cm dbh or greater were evaluated using count-plot methods (cover %, density, and basal area) to produce an importance value (Curtis and McIntosh, 1951). Heights of all conifers between 5 cm dbh and 10 cm high were also measured. Numbers of seedlings less than 10 cm tall were evaluated for 20 ft square (37 m^2) plots nested within the northwest and southeast corner of each 0.07 ha study site.

Landscape factors (slope, aspect, and elevation) were recorded for each study site. Interrelations between vegetation distribution and potential solar beam irradiation (a variable locally dependent upon slope and aspect) was assessed using tables of Frank and Lee (1966).

Conifer growth was evaluated using site index (Avery, 1967) based on height and age at dbh (1.4 m). Sapling growth rates were obtained for selected trees less than 5 cm dbh by cutting and aging stems at 2.25 ft (68.6 cm) intervals. This practice was not employed where seedling establishment was believed limiting to density of mature trees. Heights of trees over 3 m tall was determined with a slope corrected Spiegal Relaskop. Relationship between site index and elevation was assessed using regression analysis (Sokal and Rohlf, 1969)

Age-diameter data were used to estimate age-size class distribution (survivorship curves) for conifers. Survivorship curves are log densities of each species per size class used to analyze successional trends (Jackson and Faller, 1973). Nomenclature follows Munz and Keck (1959) and Munz (1968).

RESULTS

Vegetation

Three scrub and five forest community-types occur within the proposed boundaries of Babbitt Peak Research Natural Area. In order of the following discussion, these community types are: sagebrush scrub, degraded sagebrush scrub, mountain mahogany woodland, aspen forest, Washoe pine forest, western white pine forest, white fir forest, and red fir forest.

Sagebrush scrub

Sagebrush scrub is dominant over 108 ha of even grading slopes with south to west aspect or steep slopes with east aspect (AT in Figure 2). Artemesia tridentata is the prevailing species. Frequently present subshrubs and shrubs include Ribes cereum, Purshia tridentata, Symphoricarpos vaccinoides, Monardella odoratissima, Eriogonum umbellatum, Ribes Roezlii, Eriophyllum confertiflorum, and Cercocarpus ledifolius (plots 5, 9, 11; Table 1). Steep east facing exposures often possess more mesic taxa like Arctostaphylos nevadensis, Ceanothus velutinus, C. prostratus, Holodiscus microphyllus and isolated specimens of Pinus monticola (plot 5, Table 1). Herbaceous taxa present in sagebrush scrub are mostly widespread species occurring in both forested and scrub vegetation types: Sitanion Hystrix, Bromus marginatus, Gayophytum ramosissimum, Carex sp., Lupinus sp., Leptodactylon pungens (Table 1). Dry meadow communities dominated by Wyethia mollis have resulted from severe overgrazing of sagebrush scrub (plot 3; Table 1). Approximately 18 ha of this "degraded" sagebrush scrub occur within the study area, principally about the cattle driveway on Babbitt Peak's southwest spur ridge (Wm in Figure 2).

Mountain Mahogany Woodland

Mountain mahogany woodland is extensive, covering 103 ha of southwest, south and southeast aspects. Best development occurs on 67 ha of steep convex south and southwest slopes above 2,438 m (8,000 ft) (Cl in Figure 2). This community also occurs on southwest to southeast aspects with gentle

slope where its slope-aspect distribution overlaps with that of sagebrush scrub, degraded sagebrush scrub, aspen groves, and coniferous forest species (Abies concolor, Pinus jeffreyi, P. monticola and P. washoensis). However, for Cercocarpus ledifolius to occur on gentle terrain either the soil must be rocky or exposure to winds out of the southwest must be extreme (as along ridge crests) or both. Stands may be entirely dominated by Cercocarpus ledifolius or possess occasional Pinus washoensis and/or Pinus monticola. In either case frequency for Cercocarpus is high (1052 ± 271 stems/ha) resulting in 34 ± 14% cover and basal area of 41 ± 15 m^2/ha (plots 7, 9, 10; Figure 3). Two subordinate species (Sidalcea malvaeflora and Phacelia sp. are shared between mountain mahogany woodland and adjoining sagebrush scrub. Penstemon Newberryi, Cryptantha microstachys, and Chrysopsis Breweri appear most abundant within mountain mahogany woodland (Table 1). In addition to widespread species, associated taxa in mountain mahogany woodland include Artemesia tridentata and Wyethia mollis from the sagebrush scrub as well as Pedicularis semibarbata, Silene Lemmonii, and Poa sp. which also occur within coniferous forests (plots 7, 9, 10; Table 1).

Aspen Forest

Scattered within sagebrush scrub are nine distinct groves of Populus tremuloides (S.A.F. cover type 217). Aspen groves occupy 37 ha of gentle south to west facing slopes and range from scrubby thickets with numerous dead stems near ridge crests to thick clusters of small trees growing with verdant

understory adjacent to coniferous forests (plot 12; Table 1, Figure 2). Excepting local areas bordering white fir forests, aspen groves are not currently being invaded by conifers. Associated taxa vary between members of the sagebrush scrub and coniferous forests depending upon location of the aspen grove.

Coniferous Forests

Fifty-one percent or 364 ha of the Babbitt Peak study area are coniferous forests. Most extensive is white fir forest embracing 195 ha, followed by western white pine (68 ha), red fir (62 ha), and Washoe pine forest (40 ha). Ecotonal communities between coniferous forests and sagebrush scrub or mountain mahogany woodland occupy another 23.5 ha. Unlogged stands of Washoe pine and western white pine are ecologically unique.

Washoe Pine Forest:

Pinus washoensis is dominant over 40 ha of gentle to moderate sloping tablelands and upland benches with west, east, and especially south aspect between 2,316 m and 2,590 m (7,600 to 8,500 ft). Washoe pine's principal distribution is an open, nearly pure stand encompassing 35 ha on gently sloping south exposure above 2,440 m elevation on the spur ridge extending northeast from Bald Mountain (Pw in Figure 2). Here *Pinus washoensis* accounts for approximately 90% of frequency, cover, and basal area (plot 6; Figure 3). On the western "windward" wide of Bald Mountain only 1.8 ha of nearly pure Washoe pine forest occur. However, this small grove

contains Pinus washoensis up to 34 m tall and 1.4 m dbh (plot 15). The slope-aspect-elevation range of Pinus washoensis west of the Bald Mountain crest is largely occupied by sagebrush scrub, degraded sagebrush scrub, and aspen groves (At, Wm, and Pt in Figure 2).

Mixed Pinus washoensis, Abies concolor, and Pinus monticola forests occur over 4 ha between 2,316 m and 2,347 m (7,600 - 7,700 ft) in the extreme northeastern corner of the proposed natural area (Pw Ac Pm in Figure 2). (Another 9 ha of mixed Pinus washoensis forest occurs as part of this grove but are on private land north of the study area). At this site Pinus washoensis accounts for approximately 50% of basal area and cover but only 30% of frequency (plot 4; Figure 3). Relative frequency for Pinus washoensis is lower due to recent increases in Abies concolor. Additionally, Pinus washoensis occurs as an associate within 15 ha of Pinus jeffreyi, Abies concolor, and Pinus monticola forest (Ac Pw Pj Pm in Figure 2) and within 8 ha of Abies concolor and Pinus jeffreyi forest (Ac Pw Pj in Figure 2; plot 16, Figure 3). Single widely spaced Pinus washoensis also occur within marginal red fir forest (plot 17) and as scrubby specimens within mountain mahogany woodland (plots 7, 10).

Pinus monticola occurs as pure or nearly pure stands over 68 ha between 2,316 and 2,650 m elevation (7,600 to 8,700 ft) principally on gently sloping northwest to northeast exposures near ridge summits. Two essentially pure Pinus monticola stands sampled revealed an average frequency of 400 stems/ha

resulting in 57% cover and 78 m^2/ha basal area (plots 1,23; Figure 3). Dominance is shared with Abies concolor and/or Abies magnifica on steeper concave north slopes or further below crests of ridges. (These sites will be discussed with their respective fir cover types). Ecotones between Pinus monticola forest and sagebrush scrub (or degraded sagebrush scrub) are often sharp, as on the ridge running southwest from Babbitt Peak. Less distinct ecotones occur between Pinus monticola forest and sagebrush scrub on the northwest flank of Babbitt Peak (15 ha), between Pinus monticola, Pinus washoensis, and sagebrush scrub along the crest of the northeast spur ridge (5 ha), and with Pinus contorta, Pinus jeffreyi, and Abies concolor on the spur ridge running southwest from Babbit Peak (3.5 ha) (Figure 2).

White fir forest (S.A.F. cover type 211) encompasses 194 ha and is the most widespread timber type within the proposed natural area. Six sub-types can be recognized: pure Abies concolor stands (14 ha); mixed Abies concolor and Pinus monticola stands (25 ha); Abies concolor - Pinus jeffreyi forest (105 ha); mixed Abies concolor, Pinus jeffreyi, and Pinus monticola forest (12 ha); Abies concolor with Pinus jeffreyi and P. washoensis (15 ha); and stands of the three last named species with Pinus monticola (24 ha).

Nearly pure Abies concolor forests occur as dense stands of young trees approximately 100 years old in an unnamed ravine on the northwest corner of the study area between 2,316 m and 2,438 m elevation, and as mature stands on west exposure

in Badenaugh Canyon (Ac in Figure 2). Frequency within young white fir stands exceeds 1,000 stems/ha. Vegetation cover is in excess of 90% and basal area is approximately 70 m^2/ha (plot 19; Figure 3). Mature *Abies concolor* forests have many fewer stems per hectare, more basal area, and lighter cover (plot 20; Figure 3).

Abies concolor - *Pinus monticola* forests occur on the northwest slope of Badenaugh Canyon (Ac Pm of Figure 2). Plot 22 depicts a mixed stand consisting of about 70% *Abies concolor* and 30% Pinus monticola (Figure 3). Actual *Abies concolor* and *Pinus monticola* composition is reciprocal with *Pinus monticola* becoming progressively more important at higher elevation. Pure *Abies concolor* forests found at the base of the northwest aspect of Badenaugh Canyon with *Abies concolor* - *Pinus monticola* forests at mid-slope, and pure *Pinus monticola* forests of upper slopes all exhibit moderate total frequency (329 ± 176 stems/ha), high per cent cover (64 ± 10%) and total basal area (82 ± 11 m^2/ha). Such progressive reciprocal gradient in dominance between *Abies concolor* and *Pinus monticola* is rare within the Sierra Nevada and doubtless results from the absence of *Abies magnifica*, which would normally be dominant at northwest aspects between 2,300 m and 2,600 m elevation.

Pinus jeffreyi is an associate with *Abies concolor* on south and exposed west slopes (Ac Pj in Figure 2). Actual numbers of *Pinus jeffreyi* present are usually low amounting to about 5% of total frequency, but trees make large contributions

(approximately 20% each) to basal area and cover (plot 20). Low frequency has resulted from recent increases in numbers of Abies concolor within these stands (white fir frequency within plot 20 is nearly 1,400 stems/ha). Abies concolor - Pinus jeffreyi forests are, thus, developing into pure white fir forests - a change which has been accompanied by significant increase in dead and down fuels. Resulting fire hazards are extreme, particularly on southwest aspects below plot 20. Where fires have burned within Abies concolor - Pinus jeffreyi forests along the proposed natural area's northeast boundary, dense stands of Ceanothus velutinus have developed (Cv in Figure 2).

Abies concolor and Pinus jeffreyi occurring on exposed northwest or protected west slopes have Pinus monticola as a third associate. Mixed Abies concolor - Pinus washoensis forests have already been discussed.

Red fir forest (S.A.F. cover type 207) is restricted to concave sloping north aspects between 2,377 m and 2,560 m elevation (7,800 to 8,400 ft) (Am Pm and Am Pm Ac forest in Figure 2). Largest stands occur over 40 ha at the extreme north end of the study area, but this region has been selectivel logged. A smaller grove of old growth red fir occupies 22 ha on northwest facing slopes of the spur ridge running southwest from Babbitt Peak. Here Abies magnifica, Pinus monticola, and, to a lesser extent Abies concolor form mixed stands (plots 14, 17, 18; Figure 3) with Abies magnifica assuming clear dominance (importance values >200) locally (e.g. plot 18). These three

sites suggest an average percent cover, frequency, and basal area for Abies magnifica of 44 ± 7%, 148 ± 86 stems/ha, and 41 ± 29 m^2/ha respectively compared to respective average total cover, frequency, and basal area of 87 ± 12%, 624 ± 293 stems/ha, and 85 ± 20 m^2/ha.

Ecological relationships between plant communities along boundaries of the smaller "west" slope Abies magnifica grove are complex. The stand's south boundary occurs at the crest of the spur ridge where mixed Abies magnifica - Pinus monticola forest grades into open community with Abies magnifica, Pinus monticola, P. Jeffreyi, P. contorta, Juniperous oestosperma, and Abies concolor occuring among Ceanothus velutinus, Cercocarpus ledifolius, and other sagebrush scrub species (plot 13; Table 1). West and north boundaries of the grove are with white fir forest within which Pinus monticola and Pinus Jeffreyi are associates. On these flanks less steep slope and/or decreasing north aspect lead to greater exposure and the elimination of Abies magnifica from the forest. A mixed Abies concolor, Pinus Jeffreyi, and P. washoensis forest forms the northeast boundary which is coincident with an abrupt transition to northwest and west aspect along a dry ravine bottom. At its extreme western aspectional limits, Abies magnifica may have once overlapped in distribution with Pinus washoensis, as a few overmature Washoe pines still occur within the red fir forests in this area (plot 17; Table 1). Occurrence of very old Washoe pine within red fir forest suggests former forests were once more open. East boundaries for the red fir forests are with Pinus monticola

forest except for an abrupt ecotone onto rocky west facing exposure possessing Populus tremuloides and degraded sagebrush scrub communities (Figure 2).

Annual and perennial species characteristic of coniferous forests are Pyrola picta ssp. dentata, Pyrola picta, Kelloggia galioides, Penstemon oreocharis, Poa sp., and Paeonia Brownii. Pedicularis semibarbata and Silene Lemmonii are shared between mountain mahogany woodland and coniferous forests, but are more abundant in the latter. Pterospora andromedea and Hieracium albiflorum are largely confined to Washoe pine and white fir cover types, respectively, while Chimaphila umbellata was only found under cover western white pine and red fir types (Table 1).

Widespread subordinate species within coniferous forest and surrounding scrub and woodland communities are Viola purpurea, Symphoricarpos rivularis, Bromus marginatus, Sitanion Hystrix, Monardella odoratissima, Lupinus sp, Gayophytum ramosissimum, Haplopappus sp., Osmorhiza occidentalis, Penstemon speciosus, Ribes roezlii, Phacelia sp., and Ceanothus velutinus. The latter species appears to be a reliable indicator of past fires in the Babbitt Peak area. Festuca idahoensis and Melica sp. are widespread in sagebrush scrub, mountain mahogany woodland, and coniferous forests excepting white fir forests. Leptodactylon pungens and Collinsia parviflora are widespread except in western white pine and red fir cover types (Table 1).

Growth

Four conifer species were encountered in sufficient numbers to permit quantitative estimates of height and diameter growth: Abies concolor, A. magnifica, Pinus monticola, and Pinus washoensis. Sapling Abies magnifica averaged 46 ± 10 years (n = 6) to reach breast height (1.4 m). Fastest growth occurs at sites with least shrub and tree stratum cover (Figure 4). (See Table 1 for cover estimates for plots listed in Figure 4). Plot 13 possesses low, 45%, shrub and tree stratum cover, but is on a ridge crest where moisture stress may override light in limiting sapling growth.

Despite subtle differences in sapling growth rates attributed to overstory cover, growth of dominant Abies magnifica are practically uniform, averaging 0.31 m/yr between 20 and 100 years age at breast height. After 100 years at breast height trees are approximately 25 m tall (Figure 5). Minor variation in growth of mature Abies magnifica is due to restriction of this species to steep north aspects between 2,347 and 2,560 m elevation. Exceptions are isolated slowly growing red firs within nearly pure stands of Pinus monticola at higher elevation (e.g. plot 23 at 2,621 m).

Abies concolor occurs in a greater variety of sites than A. magnifica. It also illustrates wider amplitudes in growth rates both as a sapling and mature tree. Average age at breast height for 10 saplings sampled was 38 ± 14 years (Figure 4). White fir sapling growth appears negatively correlated with overstory (tree and shrub stratum) cover

except for sites at higher elevation where growth is slow even at semi-open sites (e.g. plot 22 at 2,487 m).

Growth rates of maturing Abies concolor are nearly linear between 20 and 100 years age at breast height. Average growth rate is 0.18 m/yr producing trees approximately 21 m tall after 100 years age at breast height (Figure 5). Abies concolor growing on lower slopes apparently grow faster reaching 28 m within this same time period (e.g. plot 19).

Growth for sapling Pinus monticola are relatively uniform. A sample of 10 saplings revealed an average of 45 ± 8 years to reach breast height (Figure 4). Growth rates for mature trees are more variable. Maximum growth occurs on lower slopes where this species occurs within forest dominated by Abies concolor or A. magnifica (plots 19 and 14 respectively; Figure 6); growth may average 0.25 m/yr between 20 and 100 years age at breast height and result in trees approximately 22 m tall. Trees growing on gentle convex slopes at higher elevation exhibit slightly lower growth rates (plots 1, 4) averaging 0.18 m/yr between 20 and 100 years at breast height, and reaching only 17 m height after 100 years age at breast height. At still higher elevations growth rates decline further and become more variable (plot 23; Figure 6).

Limited reproduction of Pinus washoensis resulted in only five saplings being sampled for age-height relationships. These data suggest early growth is rapid with trees attaining breast height in 38 ± 7 years. At the best sites Pinus washoensis growth is approximately equal to higher elevation Pinus

monticola, averaging 0.17 m/yr between 20 and 100 years age at breast height (plot 15). Washoe pine growing on ridge crests (plot 6) or on lower slopes on the east side of the Bald Mountain crest (plot 4) average only 0.13 m/yr between 20 and 100 years age at breast height and attain but 13.5 m at the end of this period (Figure 6). Similar growth rates prevail for _Pinus washoensis_ growing in _Cercocarpus_ woodland at relatively sheltered sites (plot 7). Height growth for Washoe pine growing in open exposed _Cercocarpus_ woodland or sagebrush scrub is strongly reduced (plot 10; Figure 6) due to repeated wind damage to crowns. Diameter growth rates for _Pinus washoensis_ at this site is typical for this species at Babbitt Peak (plot 10; Figure 7). Growth rates for _Pinus Jeffreyi_ are approximately equal to those of _Pinus washoensis_. Height growth rates for _Pinus monticola_, _Pinus washoensis_, and north slope _Abies concolor_ show progressive decline with increasing elevation (Table 2).

Structure

Age diameter relationship for _Abies concolor_ and _A. magnifica_ are similar with trees attaining approximately 40 cm after 100 years age (both measurements being taken at breast height). Subsequent growth is slower, an additional 120 years being necessary for trees to reach 60 cm diameter breast height (dbh) (Figure 7). Diameter growth rates for _Pinus washoensis_ are more constant over time. Trees reach 40 cm dbh within 100 years like firs, but are at 60 cm dbh after only 180

years, and are at 80 cm dbh after about four centuries (Figure 7). Young suppressed and codominant Pinus monticola grow slowly and are approximately 30 cm in diameter 100 years after reaching breast height. After 100 years age at breast height, most Pinus monticola have well developed crowns and diameter growth rate increases to become roughly equivalent to Washoe pine (Figure 7).

While a less accurate measure of specific site quality than age-height relationships, age-diameter data of Figure 7 combined with the age of saplings at breast height (Figure 4) provide a first approximation of ages for the various size classes used to evaluate stand structure (Table 3).

Largest Abies concolor encountered at Babbitt Peak were 124 cm dbh. Given low growth rates for all white firs of coreable size (Figure 7), low growth rates for outermost portions of large fir trees, and expected properties of the age-diameter relationship for trees, Babbitt Peak Abies concolor may be some of the oldest known - reaching up to 600 years age and possibly more. Numbers of Abies concolor stems per size class are relatively constant for size classes 1-6 (Figure 8). A distinct peak in white fir reproduction and/or survival occurs in age-size classes 8 and 9 representing establishment which occurred 350 to 450 years ago (1~~5~~625-1~~4~~525). This peak was preceeded by a century of low fir establishment. Since the late 17th Century Abies concolor establishment has increased steadily until the past 50 years. Abies concolor reproduction during the past century has been higher

than for any period represented by living fir trees within the BabbittPeak study area (Figure 8).

Increase in numbers of Abies concolor have had the greatest impact on concave bottoms of canyons below 8,000 ft. Up to 150 years ago these sites were open, perhaps dry meadows, within which Abies concolor and Pinus monticola assumed aspect dominance. Between 50 and 150 years ago dense reproduction of Abies concolor transformed these sites into young growth forests which now have approximately 90% overstory cover beneath which further reproduction of either fir or pine is restricted to etiolated specimens incapable of becoming mature trees (plot 19; Figure 9).

South facing slopes and ridge crests below sagebrush scrub are typified by Abies concolor and Pinus Jeffreyi forests like plot 20 (Figure 9). Up to 100 years ago these forests consisted of few stems per hectare from widely disparate age classes, but with Abies concolor much more abundant than Pinus Jeffreyi. Between 50 and 100 years ago a sharp increase in Abies concolor occurred leading to dense understory shade and litter accumulation. Results have been loss of vigor of many young trees, virtual cessation of Pinus Jeffreyi establishment, and decline in additional fir establishment. Pinus Jeffreyi regeneration within Abies concolor forest has apparently never occurred over long intervals. Plot 20 suggests the last period of successful establishment for Jeffrey pine ended with size class 4, approximately 150 to 200 years ago, just as the present surge in Abies concolor reproduction was beginning.

Open stands of Abies concolor (plot 21) are usually found at mid-slope, well within the forested zone about Babbitt Peak (Ac in Figure 2), and are composed of few mature trees of varied age size classes which may span four or five centuries. These sites have recently experienced a strong surge in Abies concolor establishment during the past 50 years (plot 21; Figure 9).

Upper elevation white fir forests on north aspects are usually mixed Abies concolor - Pinus monticola forests with the former more abundant at lower elevations (e.g. plot 22). Both species are present in several age-size classes, and dense reproduction (which occurs locally) appears to be neither a recent past nor present characteristic of Abies concolor - Pinus monticola forests.

Old growth Abies magnifica occur only within one small region of the proposed natural area, and much of this grove is largely Pinus monticola forest within which Abies magnifica is a principal associate (plots 14, 18; Figure 10). Local areas of this grove, however, are clearly dominated by red fir (e.g. plot 17; Figure 10). Significant numbers of seedling and sapling (size class 1) and low numbers of small trees (size class 2) occur for Abies magnifica due to a moderate intensity fire which occurred during the last 50 years (Figure 8). Beyond size class 9, ages of Abies magnifica become too speculative to permit objective interpretation. Abies magnifica structure at a given site is strongly gap-phase, with peaks and gaps varying from one study site to another (Figure 10). Significant Abies magnifica and other conifer reproduction has taken place between 50 and 100 years

ago along the ecotone between Pinus monticola - Abies magnifica forest and sagebrush scrub (plot 13; Figure 10).

Pinus monticola occurs at 15 of 18 sites examined which possessed coniferous trees (Table 1). Composite age-size class distribution indicates relatively stable or slightly increasing reproduction over the past 150 years preceeded by as much as 400 years of episodic (gap-phase) reproduction and/or survival (Figure 8). Largest trees are estimated to be between 500 and 600 years old. They occur as members of nearly pure western white pine forest which form open stands on gentle northwest slopes of Babbit Peak (plot 23). Survival from reproduction occurring 300 to 450 years ago (1525-1675) appears particularly significant (Figure 8). This period of successful establishment was followed by a brief gap centering about 275 years ago (1700) after which the current era of stable establishment commenced.

A Pinus monticola overstory does not cast sufficient shade to suppress further development of the species. However, peak establishment at a given site follows partial (or complete?) opening of the overstory, usually the result of fire or lightning strikes to one or more large trees. Reproduction up to 2,500 stems/ha in size class 1 (2-50 years age) may result (plot 1; Figure 10). Frequency above 200 stems/ha in age-size class 1 continues until tree stratum cover exceeds approximately 70%. Excepting lower tolerance of Pinus monticola to light, this sequence is similar to local reproductive cycles observed for Abies magnifica.

Due to the small total number of Washoe Pine sampled (80 trees at 7 sites, only 3 of which possessed over 40 m^2/ha of Pinus washoensis), the aggregrate age-size class distribution is too sparsely represented to be valid beyond class 9 (400 years or older). These limited data do reveal larger Pinus washoensis are very old, up to 700 or 800 years and that successful establishment has been strongly gap-phase. Significant Washoe pine establishment occurred between approximately 1525 and 1675 with a peak about the latter date. This was followed by about two centuries of progressive decline in reproduction up to age-size class 2 (1875-1925) when establishment increased abruptly. During the past 50 years, reproduction has declined somewhat (Figure 8).

Examination of specific sites reveals strongly gap-phase reproduction with peaks and gaps between sites not always coinciding (Figure 11). Moreover, recent Pinus washoensis reproduction has been accompanied by both Pinus monticola and Abies concolor establishment. Unless environmental conditions eliminate white fir and western white pine from Washoe pine forests in the near future, this recent reproduction within these groves will result in very different forest composition than at present.

Potential Solar Beam Irradiation and Distribution of Cover Types

Potential solar beam irradiation (PSBR) is a theoretical parameter reflecting the intensity of solar irradiation a surface would receive if factors which vary from day to day

(clouds, smog, dust, atmospheric moisture) are omitted. Although PSBR usually differs appreciably from actual irradiation at a given site, it provides a rapid and meaningful method for comparing energy flux of different landscapes (Frank and Lee, 1966). Potential solar beam irradiation is used here to compare "typical" slope-aspect conditions (derived from Figure 2) for the various forest, scrub, and ecotonal cover types occurring within the Babbitt Peak study area (Table 4).

Abies magnifica - *Pinus monticola* forests receive least PSBR (under 200 x 10^3 ly/yr) with late fall through late winter (November 5-February 7) values especially low (Table 4). *Pinus monticola*, occurring either alone or in association with *Abies concolor*, receive slightly more than 200 x 10^3 ly/yr. Distinguishing feature between these sites and those where *Abies magnifica* is a regular associate is higher mid-winter (December 22) PSBR of the former, although even this difference is small (Table 4). Southeast slopes possessing *Pinus monticola* forest have much higher PSBR than for any other western white pine stands (Table 4). *Pinus monticola* is able to grow at this more desiccating site because a local undulation in topography (see Figure 2) traps snow blowing from degraded sagebrush scrub within the grove. Pure *Abies concolor* forests receive over 250 x 10^3 ly/yr with winter PSBR exceeding 300 ly/day and late fall - late winter PSBR in excess of 500 ly/day (Table 4). Highest PSBR for coniferous stands occurs within *Abies concolor* - *Pinus Jeffreyi* forests (approximately 280 x 10^3 ly/yr with PSBR falling below 500 ly/day for only a few days about mid-winter).

Mountain mahogany woodland and sagebrush scrub have PSBR's which are high and approximately equal (Table 4), further suggesting a soil difference (greater percent rock in the former) as responsible for determining the distributions of these two cover types, at least on the west slopes of Bald Mountain. Potential solar beam irradiation for sagebrush scrub and ecotones between sagebrush scrub and mountain mahogany woodland and sagebrush scrub are approximately equal to that received by _Abies concolor_ - _Pinus Jeffreyi_ forest, suggesting other than aspectional causes for absence of these trees on south aspects above 2,500 m. Very low PSBR for the _Pinus monticola_ - sagebrush scrub ecotone on the northwest flank of Babbitt Peak explains presence of these pines among the sagebrush scrub when ecotones are sharp elsewhere.

Pinus washoensis vary in slope aspect and PSBR. Where PSBR is high (276×10^3 ly/yr) nearly pure _Pinus washoensis_ stands without firs occur. Where PSBR is lower as on west slopes, PSBR declines somewhat (approximately 250×10^3 ly/yr) with most of the drop coming from reduced winter insolation. At this point _Abies concolor_ may also become an associate. Where PSBR is very low, as on northeast exposure about the northeastern extreme of the proposed natural area, _Abies concolor_ and _Pinus monticola_ both become regular members of _Pinus washoensis_ stands. No significant differences occur between either the total amount or seasonal distribution of PSBR for either pure _Pinus washoensis_ forest or sagebrush scrub (Table 4).

DISCUSSION

Environmental factors believed responsible for separating major vegetation cover types within the Babbitt Peak study area are summarized in Figure 12. Cercocarpus ledifolius, the dominant of mountain mahogany woodland, occurs on steep convex slopes and/or rocky terrain with southwest to southeast exposure or wind swept summits of ridges. Coniferous species: Abies concolor, Pinus Jeffreyi, and P. washoensis are unable to withstand the desiccation implicit with extreme exposure at these sites. Results are dominance by Cercocarpus ledifolius, other sagebrush scrub species and scrubby wind damaged Pinus washoensis. Sagebrush scrub and long overgrazed, degraded sagebrush scrub are most conspicuous on gently sloping south and south-southwest exposures above 2,500 m elevation. Sharp ecotones along north-south aspectional gradients between Pinus monticola forest and sagebrush scrub suggest direct environmental restriction of this conifer from sagebrush scrub via moisture stress. Absence of Abies concolor and sporadic presence of the more exposure in? tolerant conifers (Pinus Jeffreyi and P. washoensis) are more difficult to explain, as forests possessing healthy members of each species overlap sagebrush scrub regarding potential solar beam irradiation. Low site index of isolated Pinus washoensis growing in the sagebrush scrub has been observed to be related to wind damage to the crown and not availability of soil moisture. While few seedling pines are found about mature pine trees in the sagebrush

scrub, this is also true for sites where the pines are dominant, and one ponders why pines, particularly _Pinus washoensis_, are absent from large areas of sagebrush scrub.

Pinus washoensis is limited to a few stands along the western edge of the Great Basin (Griffin and Critchfield, 1972). The salient feature of Washoe pine's distribution within the Babbitt Peak area is restriction of stands to the eastern (leeward) side of the Bald Mountain crest, or to obviously protected sites west of the Bald Mountain crest. (Landscape similar to that possessing _Pinus washoensis_ on the west side of the Bald Mountain Range is vegetated with sagebrush scrub, degraded sagebrush scrub, or aspen groves). Subtle edaphic differences could be responsible for this distribution, although this is unlikely as both the sagebrush scrub and Washoe pine forest are largely confined to tertiary volcanic substrate (andesite), (Burnett and Jennings, 1962). Overlapping amounts of potential solar beam irradiation for sagebrush scrub and _Pinus washoensis_ stands on the spur ridge running northeast from the Bald Mountain crest reduce the likelihood this distribution can be attributed to local energy balance resulting from slope-exposure alone. West slope sagebrush scrub communities may be subject to frequent winds out of the southwest, the desiccating effects of which are antagonized by thermal inversion centering about 2,500 m elevation. Winds from the southwest would also increase susceptibility of west slope sites to infrequent conflagration type fires. This latter point deserves further explanation.

South slopes of the Bald Mountain Range extend as more or less even sloping terrain down to surrounding rolling hills vegetated with Pinus Jeffreyi forest. Much of this Pinus Jeffreyi forest must have contained only light fuels before the arrival of white man(and subsequent grazing, logging, and fire control) due to burning by Maidu Indians (Kroeber, 1925). It was, thus, improbable fires like the disastrous Donner Ridge Fire of 1959 could occur. Nevertheless, fires could have covered large areas possessing light fuels if they were driven by strong winds. Such fires could become more intense as they reached the slopes of the Bald Mountain Range and began to ascend through Abies concolor - Pinus Jeffreyi forest of south and southwest slopes. Upon reaching terrain currently occupied by sagebrush scrub about the summit of Babbitt Peak, a wind driven fire could be sufficiently intense (due to slope permitting fire to preheat fuels in its path) to burn into the crown even if surface fuels were light. However, upon reaching the summit of Bald Mountain, even conflagration type wildfires could no longer preheat fuels in its path. Crown fires would subside to the forest floor as they moved to the east across the spur ridge containing the Pinus washoensis grove. This would be particularly true if surface fuels were light due to local lightning fires.

While intense upslope fires are also probable from the east and northeast coming out of Upper Long Valley, local topography below the Pinus washoensis groves is replete with rocky cliff and talus areas which serve as natural firebreaks

to prevent fires from gaining direct access to the summit via the spur ridge. Field evidence of this phenomenon comes from an intense upslope fire which burned to the north of the proposed natural area but was deflected from the northern periphery of the Washoe pine stand by natural rock firebreaks and local basin morphology. An older burn evident today as a dense stand of *Ceanothus velutinus* on the northeast flank of the natural area (see Cv in Figure 2) burned up to the boundary of the *Pinus washoensis* area but was prevented from entering the stands due to a wide expanse of barren rock cliff and talus slope. Evidence of lightning strikes and small fire scars at the bases of older trees suggest stands were not subjected to severe fire for at least the past 500 years (the estimated age of larger Washoe pines).

A significant area of gently sloping terrain possessing northeast and east aspect along the Bald Mountain crest at the extreme north central boundary of the proposed natural area lacks *Pinus washoensis*, and is vegetated with sagebrush scrub. Neither does this site possess topographic protection from fires coming upslope from the northeast. Considering the limited distribution of *Pinus washoensis*, long intervals between periods of successful establishment, and slow growth of mature trees, even infrequent destruction of these stands by fire could eliminate the species from a given area. This problem becomes particularly critical since lower slope *Pinus washoensis* groves are already being invaded by white fir and western white pine which will sharply increase fire hazards

in these areas over the coming years. A comprehensive study to thoroughly investigate factors responsible for establishment, growth, dominance, and reproduction of Pinus washoensis and the causes for invasion of lower slope groves by other conifers is urgently needed.

Abies concolor is experiencing a strong upsurge within white fir forests. This upsurge commenced between 100 and 150 years ago with sharp increases in Abies concolor within previously open fir - pine forests of gently sloping canyon bottoms below 7,800 ft. elevation. At the same time or shortly after increase in Abies concolor within canyon bottoms, this "invasion" had also begun within south slope Abies concolor - Pinus Jeffreyi forests. During the past 50 years, Abies reproduction within canyon bottoms and south slope fir-pine forests has diminished somewhat, but a strong upsurge has occurred within understories of nearly pure white fir forests on middle slopes with west aspect. It becomes clear ascendance of Abies within white fir forests has been progressive, starting from lower elevations and south slopes and moving to higher elevations and more northerly aspects. Upper elevation Abies concolor - Pinus monticola forests do not yet show discernable increases in Abies concolor. A nearly similar pattern, where Abies concolor has invaded open forests adjacent to dry meadows 100 to 150 years ago and subsequently become abundant within semi-open fir-pine forests, but has not invaded upper elevation Abies concolor or Abies magnifica stands has been observed at Onion Creek, on the upper watershed of the

to prevent fires from gaining direct access to the summit via the spur ridge. Field evidence of this phenomenon comes from an intense upslope fire which burned to the north of the proposed natural area but was deflected from the northern periphery of the Washoe pine stand by natural rock firebreaks and local basin morphology. An older burn evident today as a dense stand of Ceanothus velutinus on the northeast flank of the natural area (see Cv in Figure 2) burned up to the boundary of the Pinus washoensis area but was prevented from entering the stands due to a wide expanse of barren rock cliff and talus slope. Evidence of lightning strikes and small fire scars at the bases of older trees suggest stands were not subjected to severe fire for at least the past 500 years (the estimated age of larger Washoe pines).

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North Fork of the American River 32 km south of the Babbitt Peak study area (Talley, 1977).

Causes for the invasion of semi-open to open white fir forests by Abies concolor are speculative. One hypothesis is that Indian burning maintained open fir-pine forests on gentle terrain below 8,000 ft elevation. Following first contact with white settlers in the 1850's, aboriginal populations declined precipitously ending fire management practices with consequent survival of Abies concolor reproduction which were able to grow above the browse line by the time of Anglo-American cattle and sheep grazing became significant factors in the area in the late 1800's. Data supporting this hypothesis are observations that the Sierra Maidu Indians, who inhabited terrain about BabbittPeak, "...frequently burned over the country, often annually..." (Kroeber, 1925). Direct evidence of white man's diseases ravaging Maidu Indians within the Central Valley and Foothills is available (Cook, 1943) and it is reasonable that these Indians who learned to flee the very presence of any white men could have carried pestilence to the more remote tribal population. Direct correlation between demise of Indian populations and ascendence of Abies concolor within fir - pine forests has been shown for southern Sierra Nevada (Vankat, 1970). According to this "fire" hypothesis, later increases in fir regeneration on more sheltered aspects at higher elevation would result from effective suppression of lightning and man-caused fires in the 1930's.

An alternative hypothesis would suggest primary climatic causes for fluctuations in white fir reproduction. Comparison of ring widths of White Mountain _Pinus aristata_ populations growing about the drought sensitive lower forest border and temperature sensitive upper tree line suggests temperature-moisture cycles for the region for the past 1,150 years (LaMarche, 1974). This record reveals warm dry climate since the 1930's, preceeded by warm moist conditions between approximately 1930 and 1860, which ended over two centuries of cool dry weather (1860 to 1630). Prior to 1630, climate had been cool-moist (1630 to 1350). Periods of high _Abies concolor_ establishment and survival at Babbitt Peak coincide with either warm-moist or cool-moist climatic periods, while depressions are related to dry periods. Progressive increase in elevation of sites invaded by _Abies concolor_ also coincide with warmer conditions prevailing over the past century. It is also notable that the only area where significant _Abies concolor_ populations have recently become established are on middle elevation west slopes - sites with aspect favorable to moisture compensation due to much reduced potential solar beam radiation.

Critical to determining which, if either, of these hypotheses can be accepted will be a determination whether or not larger white firs (size classes 6-12) are really as old as our age-diameter data suggest. (This can be accomplished by coring and aging the outer 10" of larger white firs and comparing these data with age diameter data derived from stumps at nearby logging operations.) If these trees are as old as

existing data suggest, the climatic hypothesis will be most attractive for explaining trends in white fir establishment. If older trees grew much faster as young maturing trees than do trees currently maturing within these groves, we must accept that earlier forests were much more open in the past, probably due to frequent stand thinning by fire. Naturally, our age-size class data for white fir will also have to be revised. Should age-size class data be confirmed, these trees will rank among some of the oldest of their species known (Fowells, 1965), a discovery not unlikely considering the semi-arid climate of the Babbitt Peak area which would promote slow growth and modest size.

Abies magnifica (confined to northeast to northwest slopes between 2,377 and 2,560 m elevation with approximate 20° slope) receives little direct beam radiation during winter - a condition favoring snow accumulation. These data combined with absence of red fir seedlings and saplings from white fir sites adjacent to Abies magnifica stands suggest moisture is limiting the distribution of this species at Babbitt Peak. Despite probable moisture stress, Abies magnifica age-size class structure indicate overall stability. Age-size class distributions for individual 0.07 ha plots are strongly gap-phase, indicating different stages of development of this true climax species within the grove. Similar phenomena have been observed within more extensive red fir stands in the central Sierra Nevada (Talley, 1976, 1977).

Pure *Pinus monticola* forests are rare in the Sierra Nevada where this species is most commonly an associate within the red fir cover type (S.A.F., 1954). At Babbitt Peak pure *Pinus monticola* stands result from presence of north-facing slopes above the elevational limits of *Abies concolor* which are also too dry for *Abies magnifica* (the usual Sierra Nevada dominant at these aspects and elevations). Evidence for this hypothesis derives from the near absence of *Abies concolor* above 2,500 m, its decreasing site index on north facing slopes with increasing elevation, and the very low site index of rare *Abies magnifica* found within essentially pure *Pinus monticola* forest. Reduction in site index of *Pinus monticola* with increasing elevation is also observed and does not appear to be related to potential solar beam radiation - a more likely cause is a pronounced temperature inversion and wind-induced desiccation at higher elevation. *Pinus monticola* stands exhibit over-all stability despite some gap-phase establishment among oldest trees. Reproduction and survival over the past 200 years has been more steady than for the previous five centuries, although fire, insects, and/or disease may yet inflict differential mortality within the youngest four age-size classes.

RECOMMENDATIONS

Additional study will be necessary before management recommendations can be made for the Babbitt Peak region. Particularly sensitive areas for future study should be early growth rates of large conifers and more complete

age-size class data - especially for Pinus washoensis. Babbitt Peak represents a most outstanding botanical resource which deserves natural area status. Prominent botanical features rendering this area unique are: pure Pinus monticola forests (a rarity within the Sierra Nevada), old growth Pinus washoensis forest, marginal Abies magnifica forest (most examples of this stand type have been logged), and varied types of Abies concolor forests which may contain very old trees for this species. Additional features are numerous ecotones between "Sierra Nevada" coniferous forests and montane "Great Basin" sagebrush scrub. I thoroughly recommend this area be studied until ecological relationships between plant communities are known on a factual basis. Once known, data must be employed to develop management schemes capable of preserving this complex region in its natural state. Inclusion of lower elevation second growth Pinus Jeffreyi - Abies concolor forest and Pinus Jeffreyi forest along the western boundary, and Pinus washoensis stands on private land along the northeastern boundary of the proposed study area are future goals which could add measurably to the ecological integrity of the proposed natural area.

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Table 1. Landscape factors and a partial list of species and potential species-plots groupings for forest vegetation within Babbitt Peak Study Area.

Slope	10°	11°	12°	30°	13°	10°	8°	11°	16°	11°	17°	11°	9°	12°	22°	17°	17°	27°	20°	23°	12°	10°
Aspect	140°	290°	175°	70°	185°	130°	215°	145°	235°	level	260°	185°	285°	280°	305°	260°	290°	320°	285°	305°	315°	280°
Elevation in m	2521	2640	2502	2475	2579	2557	2573	2518	2463	2420	2390	2402	2341	2341	2487	2390	2438	2435	2475	2576	2621	2496
	3	8	11	5	9	7	10	6	15	4	16	20	19	21	22	17	13	14	18	1	23	12
Sagebrush Scrub																						
Wyethia mollis	3		1		1	+	2	2				+		+			+					
Purshia tridentata	+		1														+					
Ribes cereum	1	+	+																			
Ceanothus prostratus				+																		
Ceanothus velutinus				+																		
Holodiscus microphyllus				+																		
Artemisia tridentata		4	3	3	3																	
Arctostaphylos nevadensis				2																		
Mountain Mahogany Woodland																						
Cercocarpus ledifolius																						
shrub stratum				+	4	1	2										+					
herb stratum			+		1	3	4															
Cryptantha sp.					+	+	+	+									+					
Chrysopsis Breweri					+	+	+	+														
Sidalcea malvaeflora	+		+		+	+	+	+														
Phacelia sp.	+	+			+	+	+	+	+													

Table 1. Continued

	3	8	11	5	9	7	10	6	15	4	16	20	19	21	22	17	13	14	18	1	23	12
Coniferous Forests																						
Pedicularis semibarbata						+	+	+	+	+						+		+	+		+	
Silene Lemmonii						+	+			1		+					+			+		
Poa sp.			+			+	+	1			+		+			+	+	+				+
Pyrola picta								+	+	+	+	+	+		+	+		+	+	+		+
Pyrola picta ssp. dentata								+		+					+	+		+	+	+		
Penstemon oreocharis									+		+	+		+	+	+		+	+		+	
Kelloggia galioides		+							+		+		+		+		+	+	+	+		
Paeonia Brownii								+	+				+		+		+	+	+	+		
Phlox diffusa								+	+	+	+	+	+	+		+	+	+	+			
Helianthella californica										+										+		
Corallorhiza maculata											+											
Pinus washoensis																						
tree stratum						1	1	4	3	3												
shrub stratum								1	2	1	1											
herb stratum								1			+											
Pterospora andromedea								+	+	+												
Pinus Jeffreyi																						
tree stratum								+		2	1		+				+					
Abies concolor																						
tree stratum									+	1	+	3	5	3	4	3	1	1				
shrub stratum									2	2	2	2	1	1	1	2	+	+	+	+		
herb stratum										1	2	1		2	+	+						
Hieracium albiflorum									+	+		+	+									
Abies magnifica																						
tree stratum																3	2	3	3		+	
shrub stratum																1	1	1				
herb stratum																1		+	+		+	

Table 1. Continued

	3	8	11	5	9	7	10	6	15	4	16	20	19	21	22	17	13	14	18	1	23	12
Pinus monticola																						
tree stratum				1						1			+		2	2	2	3	3	4	4	
shrub stratum			1	+					+	1				+	+	1	2	2	2	3	1	
herb stratum						+				+					+			1	+	2	1	
Chimaphila umbellata						+									+	+		+	+	+	+	
Aspen Forest																						
Populus tremuloides																						
tree stratum																						2
shrub stratum																						4
herb stratum																						2
Widespread Species																						
Bromus marginatus	+	+	+	+			+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sitanion Hystrix		+	+	+	1	1	1	+	1	+	+	1	+	+	+	+	1	+	+	1		+
Symphoricarpos rivularis		1		+	+	+	+		1	+	+	+	+			+		+	+		+	+
Monardella odoratissima		+		+		1	+	1	2	1	+	1	+	1	+	+	1	+	+	2	+	+
Festuca idahoensis	+	+	+	+	1	2	+		+	+	+					+	+	+	+		+	+
Lupinus sp.		+	+	+		+		+		+						+	+	+		1		
Carex sp.		2			1	1	+		+	+	2	+	+		+		+		+	2	1	
Gayophytum ramosissimum	1		+	+			+	+	+	+	+	+		+	+		+					+
Haplopappus sp.		+		1		+	+		+	+				+			+			+	+	
Leptodactylon sp.	+	+		+		+		+		+												
Osmorhiza occidentalis	+					1		+	+		+											+
Melica sp.		+				+			+					+	+							+
Penstemon speciosus		+				+		+		+							+		+	+		
Ribes roezlii					+		+				+			+								
Phacelia sp.					+	+					+						+			+		

Table 2. Decline in Growth Rate (Site Index) of Babbitt Peak Conifers With Increasing Elevation.

Pinus monticola

Plot	Site Index	Elevation
19	25	2,340m
19	20	2,340
4	17	2,420
4	16	2,420
14	20	2,435
14	21	2,435
14	21.5	2,435
18	22.5	2,475
18	17.5	2,475
22	17	2,487
22	14	2,487
1	15.5	2,576
1	16	2,576
23	14.5	2,621
23	9	2,621

Site Index = 101 - 0.034(Elev)
$r^2 = 0.56$, $n = 15$

Abies concolor(NW slope)

Plot	Site Index	Elevation
19	29	2,341
19	27	2,341
17	29	2,408
14	23	2,435
22	24	2,487
22	18	2,487

Site Index = 146 - 0.0500(Elev)
$r^2 = 0.60$, $n = 6$

Pinus washoensis

Plot	Site Index	Elevation
16	19	2,390m
4	14	2,420
4	14	2,420
15	17.5	2,463
15	18	2,463
6	16.5	2,518
7	13	2,557
10	7	2,573

Site Index = 107 - 0.0371(Elev)
$r^2 = 0.42$ $n = 8$

Abies concolor(W and SW slope)

Plot	Site Index	Elevation
21	16	2,341
21	24	2,341
16	21	2,390
16	23	2,390
16	18	2,390
20	20	2,402
20	22	2,402
20	19	2,402
13	20	2,438
13	18	2,438
13	22	2,438
15	24	2,463

Site Index = 0.0138(Elev) - 12.6
$r^2 = 0.04$, $n = 12$

Table 3. Suggested Age-Diameter Classes for Babbitt Peak Conifers.

	Age-Class	Size Class by Species			
		Abies concolor	Abies magnifica	Pinus monticola	Pinus washoens
1	0-50 yrs	0-2.4m ht	0-1.7m ht	0-1.8m ht	0-2.2m h
2	51-100	2.4m ht to 30cm dbh	1.7m ht to 26cm dbh	1.8m ht to 15cm dbh	2.2m ht to 28cm dbr
3	101-150	30cm-47	26 - 49	15 - 32	28 - 36
4	150-200	47 - 57	49 - 58	32 - 49	36 - 57
5	201-250	57 - 65	58 - 65	59 - 61	57 - 69
6	251-300	65 - 72*	65 - 73*	61 - 68*	69 - 77
7	301-350	72 - 79*	73 - 81*	68 - 75*	77 - 84
8	351-400	79 - 88*	81 - 89*	75 - 82*	84 - 91*
9	401-450	88 - 95*	89 - 97*	82 - 90*	91 - 97*
10	451-500	95 - 102*	97 - 105*	90 - 97*	97 - 103
11	501-550	102 - 109*	105 - 113*	97 - 104*	103 - 109
12	551	109*	113*	104*	109*

* Estimate based upon previous character of age diameter relationship

Table 4. Potential Solar Beam Irradiation of Typical Slope-Aspect Combinations for Babbitt Peak Forest, Scrub, and Ecotonal Cover Types.[1]

Potential Solar Beam Irridiation by Cover Type

ver type	Abies magnifica Pinus monticola	Pinus monticola	Abies concolor Pinus monticola	Abies concolor
pect	NW	NNW,NNE	NW	W
ope %	40%	25%	35%	30%
ne 22[2]	964 Ly/day	1,000 Ly/day	977 Ly/day	1,002 Ly/day
y 3, Aug 10	814	849	831	909
r 31, Sept 23	525	553	547	698
b 7, Nov 5	255	271	276	560
c 22	135	144	153	335
tal[3]	198.4	207.7	205.2	251.4
[4]	0.38	0.40	0.39	0.48

ver type	Abies concolor Pinus Jeffreyi		Pinus washoensis		Pinus washoensis, P.monticola,Abies concolor
spect	S	SSW	W	SE	NE
lope %	20%	20%	30%	20%	35%
une 22	1,001	1,003	1,002	1,009	977
ay 3, Aug 10	949	947	909	943	831
ar 21, Sept 23	805	797	698	776	547
eb 7, Nov 5	555	597	560	564	276
ec 22	493	480	335	443	153
otal	284.8	282.5	251.4	276.0	205.2
I	0.54	0.54	0.48	0.53	0.39

---

[1] Data derived or interpolated from Frank and Lee (1966) using tables for 40° N Latitude.

[2] Potential solar beam irradiation in Langleys per day for representative dates listed.

[3] Total potential solar beam irradiation per year in thousands of Langleys.

[4] RI = Radiation Index, the percent of potential sunlight striking a unit surface over one year.

Table 4. continued

Potential Solar Beam Irradiation by Cover Type

Cover type	Populus tremuloides		Pinus washoensis Artemisia tridentata	Pinus monticola Artemisia tridentata
Aspect	S	W	Level	WNW
Slope %	15%	25%		20%
June 22	1,010	1,008	1,013	1,010
May 3, Aug 10	945	913	923	868
Mar 31, Sept 23	786	699	703	584
Feb 7, Nov 5	609	459	457	306
Dec 22	661	334	329	177
Total	279.1	252.0	253.7	217.2
RI	0.53	0.48	0.48	0.41

Cover type	Cercocarpus ledifolius Artemisia tridentata		Cercocarpus ledifolius		Artemisia tridentata	
Aspect	SW	WSW	WSW	SE	S	SSW
Slope %	30%	20%	35%	60%	15%	20%
June 22	996	1,013	996	936	1,010	1,003
May 3, Aug 10	946	933	930	926	945	948
Mar 31, Sept 23	804	743	763	850	786	797
Feb 7, Nov 5	608	515	551	702	609	597
Dec 22	493	392	431	601	461	480
Total	284.1	265.6	271.0	296.7	279.1	282.5
RI	0.54	0.51	0.52	0.56	0.53	0.54

FIGURE CAPTIONS

Figure 1. Topographic gradients and location of 0.07 ha study sites within Babbitt Peak Candidate Research Natural Area.

Figure 2. Distribution of vegetation types within Babbitt Peak Research Natural Area. Letters stand for scientific names of dominant species: Ac, _Abies concolor_; Am, _Abies magnifica_; At, _Artemisia tridentata_; Cl, _Cercocarpus ledifolius_; Cv, _Ceanothus velutinus_; Pc, _Pinus contorta_; Pj, _Pinus Jeffreyi_; Pw, _Pinus washoensis_; Pt, _Populus tremuloides_; Wm, _Wyethia mollis_.

Figure 3. Count-plot data for arboreal species within 0.07 ha plots within Babbitt Peak Candidate Research Natural Area.

Figure 4. Age-height relationships for selected conifer saplings growing within the Babbitt Peak study area.

Figure 5. Height-age relationship for _Abies magnifica_ and _A. concolor_ within the Babbitt Peak study area. Numbers represent plots for representative trees. Age was determined at breast height (1.4 m) and height is standardized to 100 years at breast height to give a site index.

Figure 6. Height-age relationship for _Pinus monticola_ and _P. washoensis_ within the Babbitt Peak study area. Numbers indicate plots for representative trees. Age was determined at breast height (1.4 m) and height is standardized to 100 years at breast height to give a site index.

Figure 7. Age-diameter relationship for _Abies concolor_, _A. magnifica_, _Pinus washoensis_, and _P. monticola_ within the Babbitt Peak study area. Diameters and ages were measured at breast height (1.4 m). Numbers indicate plots from which trees were sampled.

Figure 8. Survivorship curves for four conifers within the Babbitt Peak study area. Diameters for various age classes are given by species in Table 4.

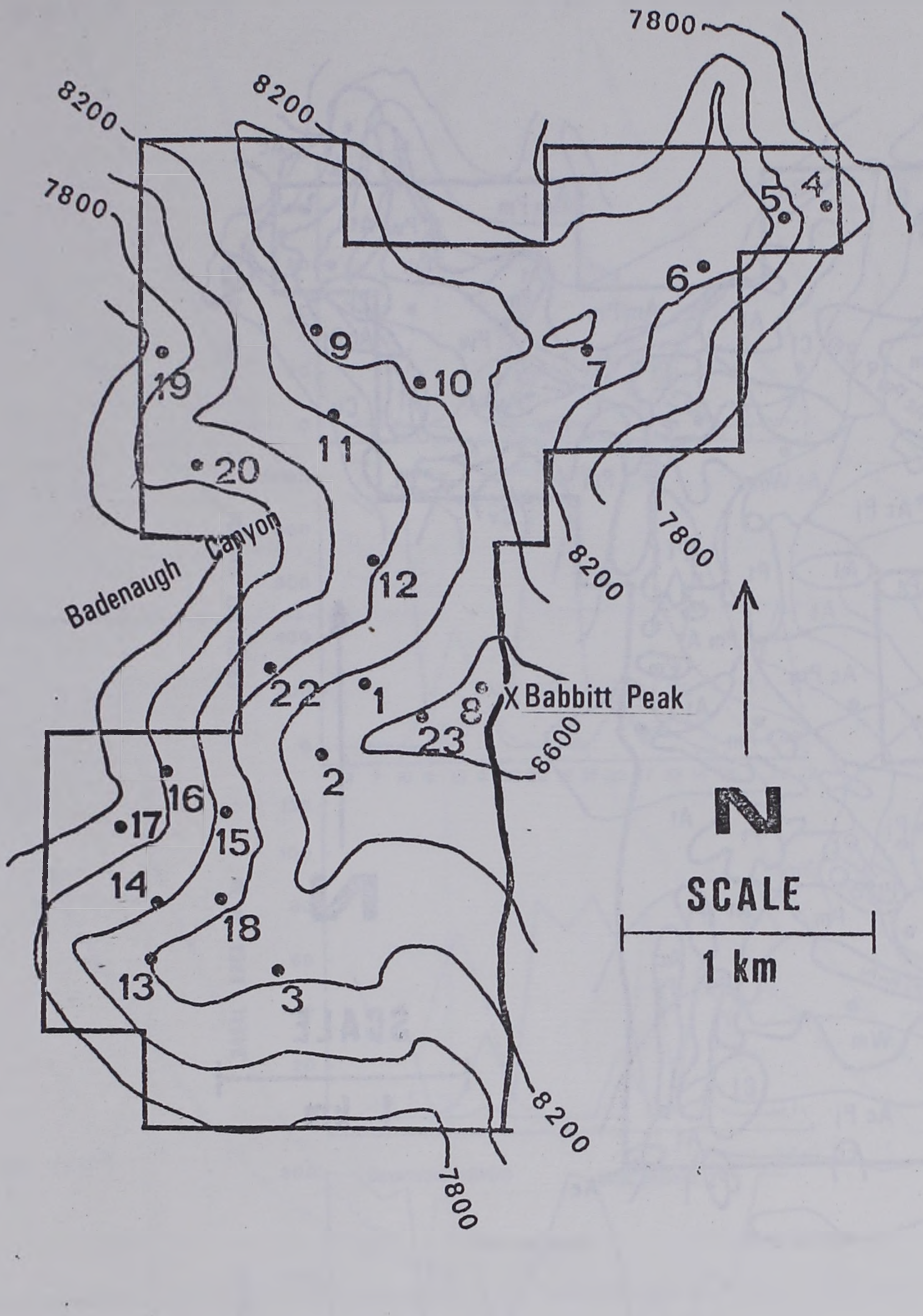
Figure 9. Survivorship curves for plots representative of _Abies concolor_ forests within Babbitt Peak Candidate Research Natural Area. Diameters for various age classes are given for each species in Table 4, except that _Pinus Jeffreyi_ age-diameter data were taken from the Washoe pine age-diameter curve.

Figure 10. Survivorship curves for plots representative of _Pinus monticola_, mixed _Pinus monticola_ - _Abies magnifica_, _Abies magnifica_, and ecotonal forests. Height and diameters for age-size classes are given by species in Table 3.

Figure 11. Survivorship curves for plots representative of _Pinus washoensis_ forest. Diameters for various age-classes are given by species in Table 3.

Figure 12. Probable interrelations between plant communities within BabbittPeak Candidate Research Natural Area. Arrows indicate changes in vegetative composition taking place with changing physiographic or other factors listed. Decreased exposure reduces fall, winter, and spring potential solar beam irradiation (PSBR), compensating for moisture. Increased elevation is believed to subject plants to greater effects of thermal inversion - aggravating moisture stress.

Figure 1


7800
8200
8200
7800
Badenaugh Canyon
X Babbitt Peak
8600
8200
7800
8200
7800
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
22
23
N
SCALE
1 km

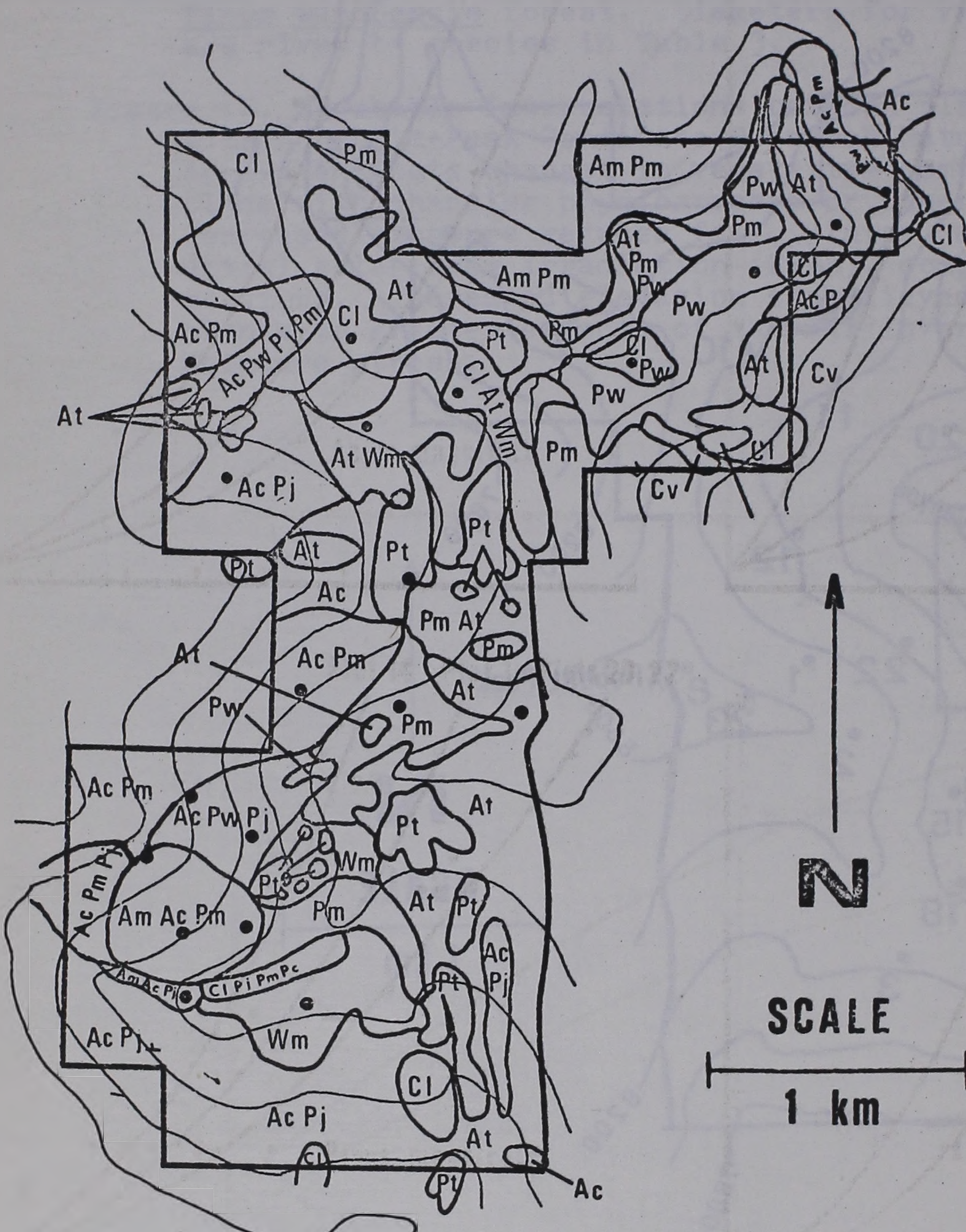
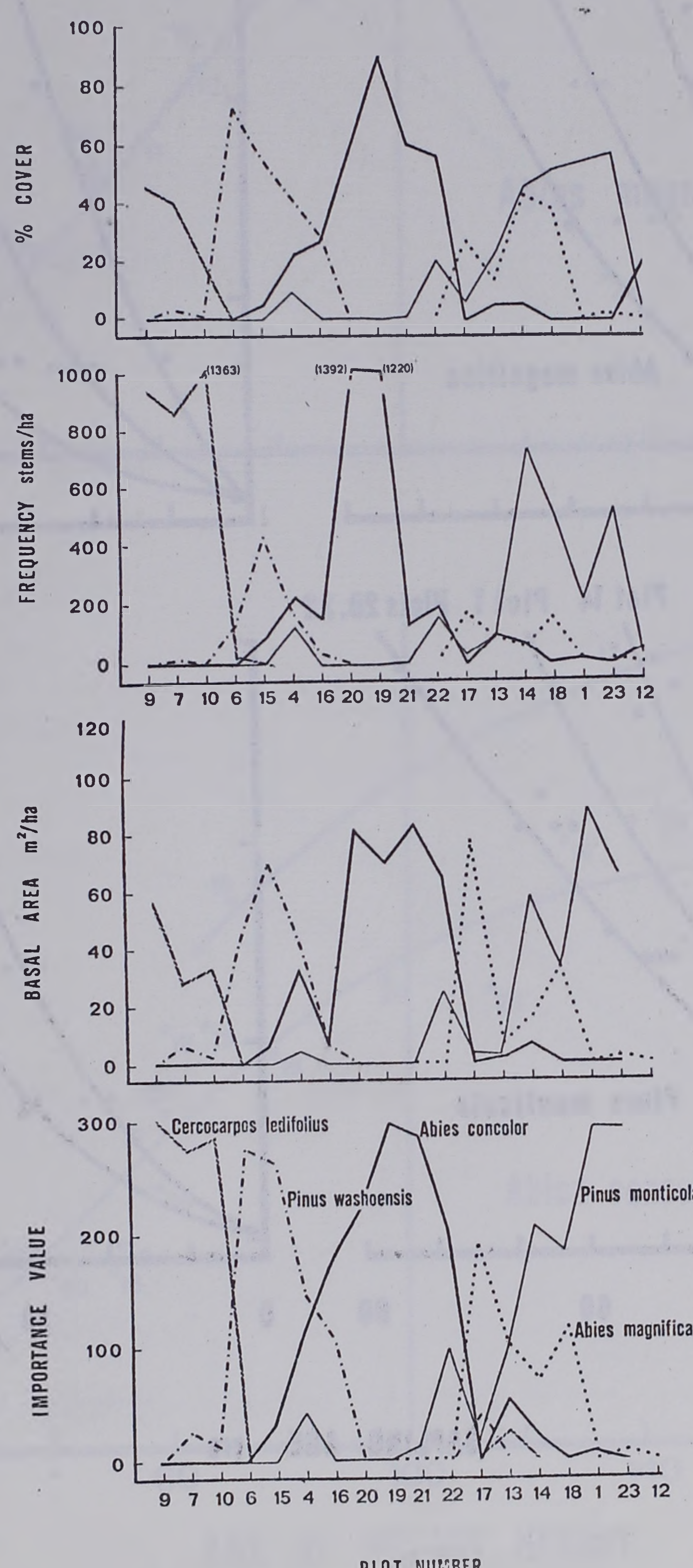
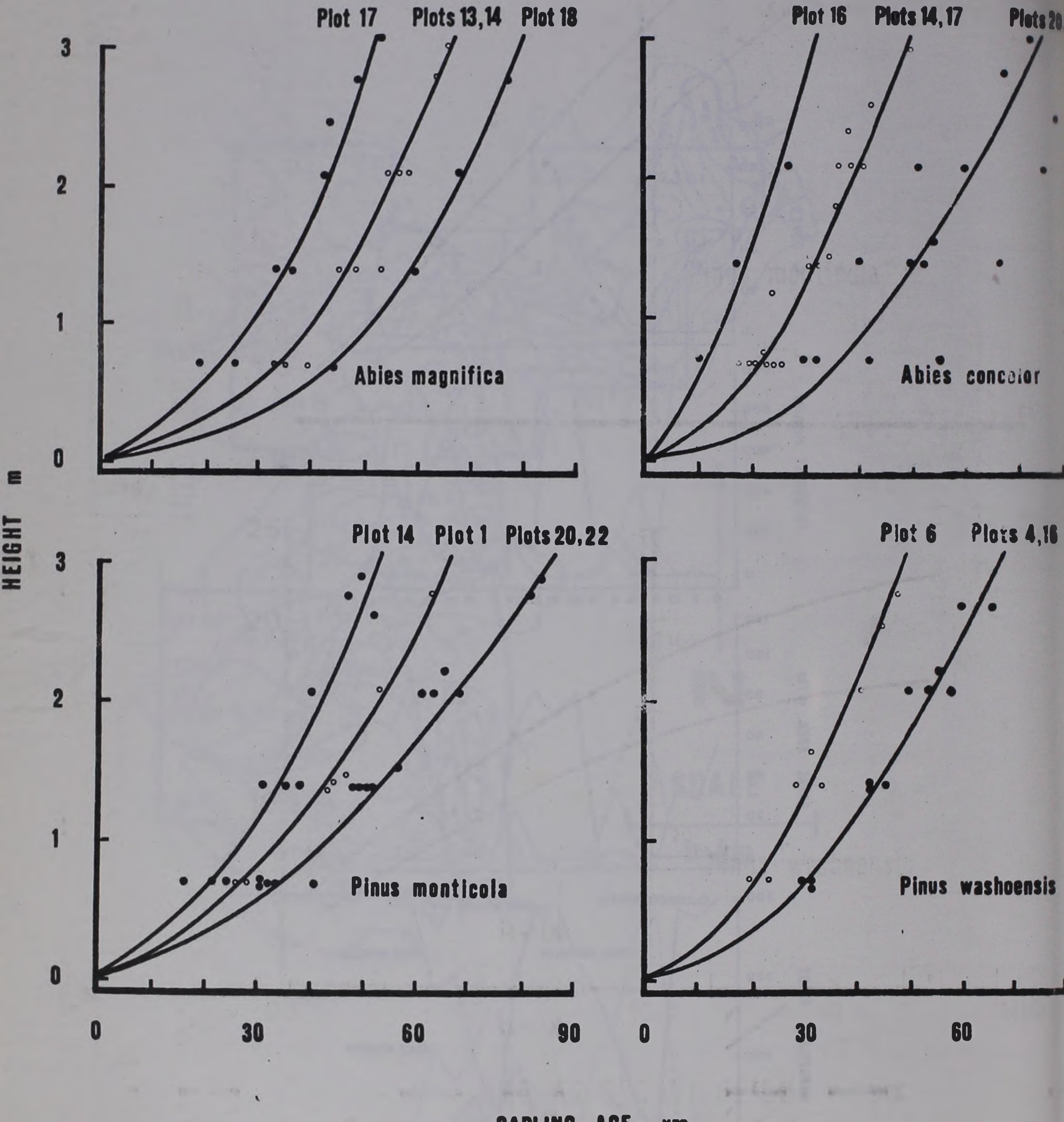
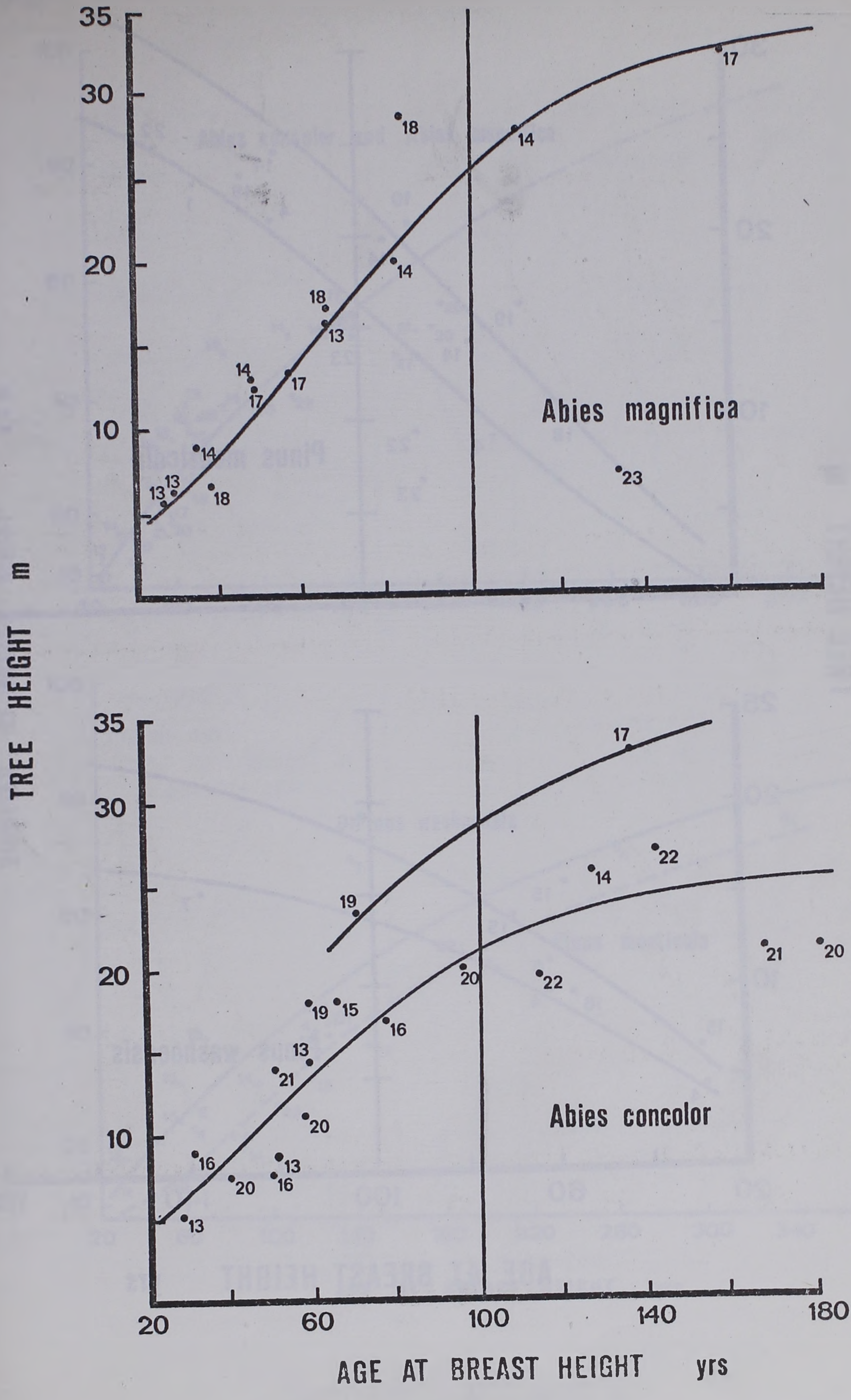

Cl
Pm
Am Pm
Ac
Ac Pm
Pw
At
Pm
At
Pm
Pw
Cl
At
Am Pm
Ac Pm
Ac Pw Pj Pm
Cl
Pt
Pm
Cl
Pw
Pw
Ac Pj
At
Cv
Cl At Wm
At Wm
Pw
Pm
Ac Pj
Cl
Cv
At
Pt
Pt
Pt
Ac
Pm At
Pm
At
Ac Pm
At
Pw
Pm
Ac Pm
Ac Pw Pj
Pt
At
Ac Pm Pj
Wm
Pt
Am Ac Pm
Pm
At
Pt
Ac
Pj
Am Ac Pj
Cl Pj Pm Pc
Pt
Ac Pj
Wm
Cl
Ac Pj
At
Cl
Pt
Ac
N
SCALE
1 km

Figure 3


% COVER
FREQUENCY stems/ha
(1363)
(1392)
(1220)
BASAL AREA m^2/ha
IMPORTANCE VALUE
Cercocarpos ledifolius
Abies concolor
Pinus washoensis
Pinus monticola
Abies magnifica
9 7 10 6 15 4 16 20 19 21 22 17 13 14 18 1 23 12
PLOT NUMBER



Plot 17
Plots 13,14
Plot 18
Abies magnifica
Plot 16
Plots 14,17
Abies concolor
Plot 14
Plot 1
Plots 20,22
Pinus monticola
Plot 6
Plots 4,16
Pinus washoensis
HEIGHT m
0
1
2
3
0
30
60
90
SAPLING AGE yrs


35
30
20
10
18
14
14
18
13
14
17
17
13
13
14
18
17
23
Abies magnifica
35
30
20
10
17
19
22
14
21
20
20
22
19
15
16
13
21
20
16
13
20
16
13
Abies concolor
20
60
100
140
180
TREE HEIGHT m
AGE AT BREAST HEIGHT yrs

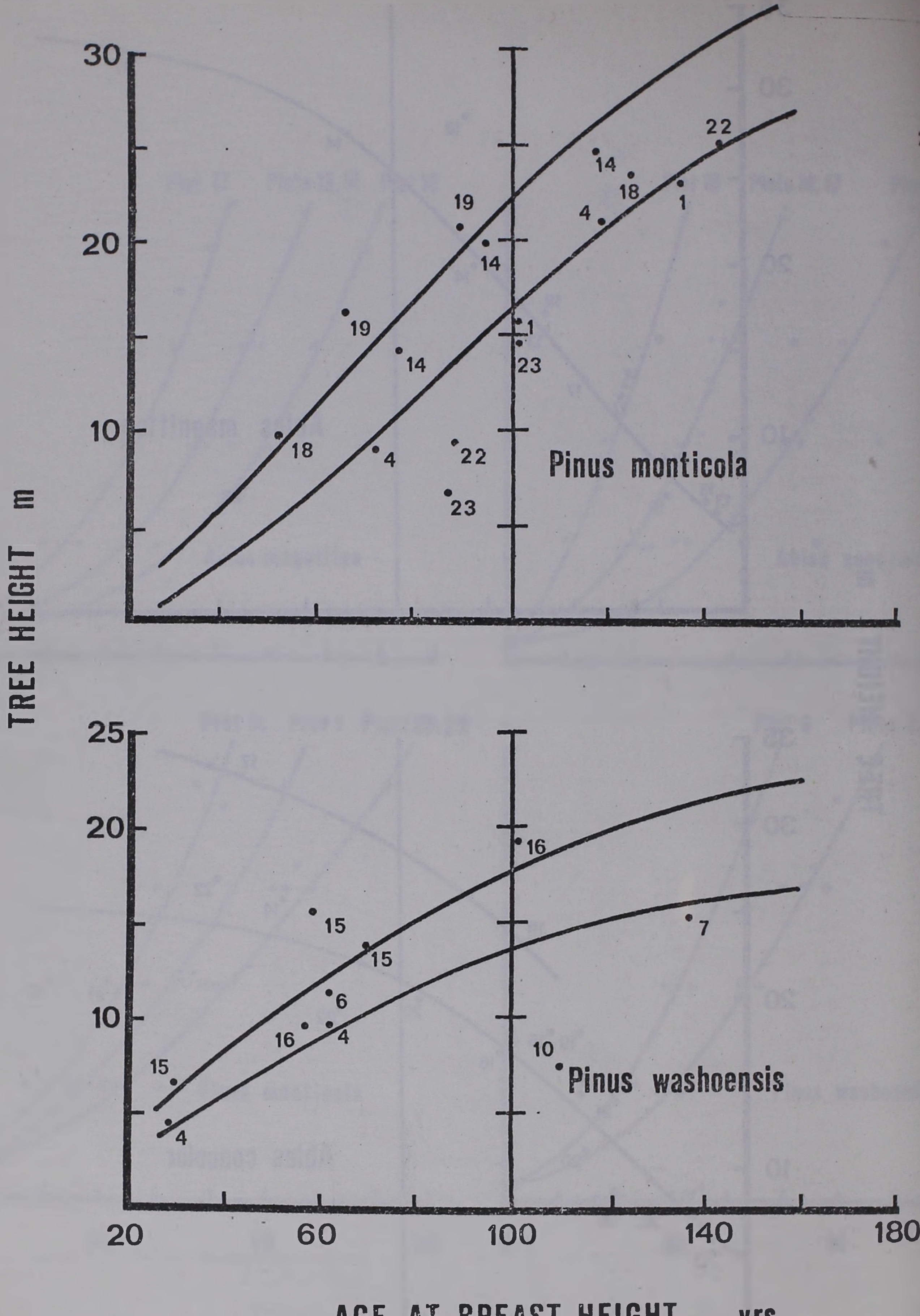
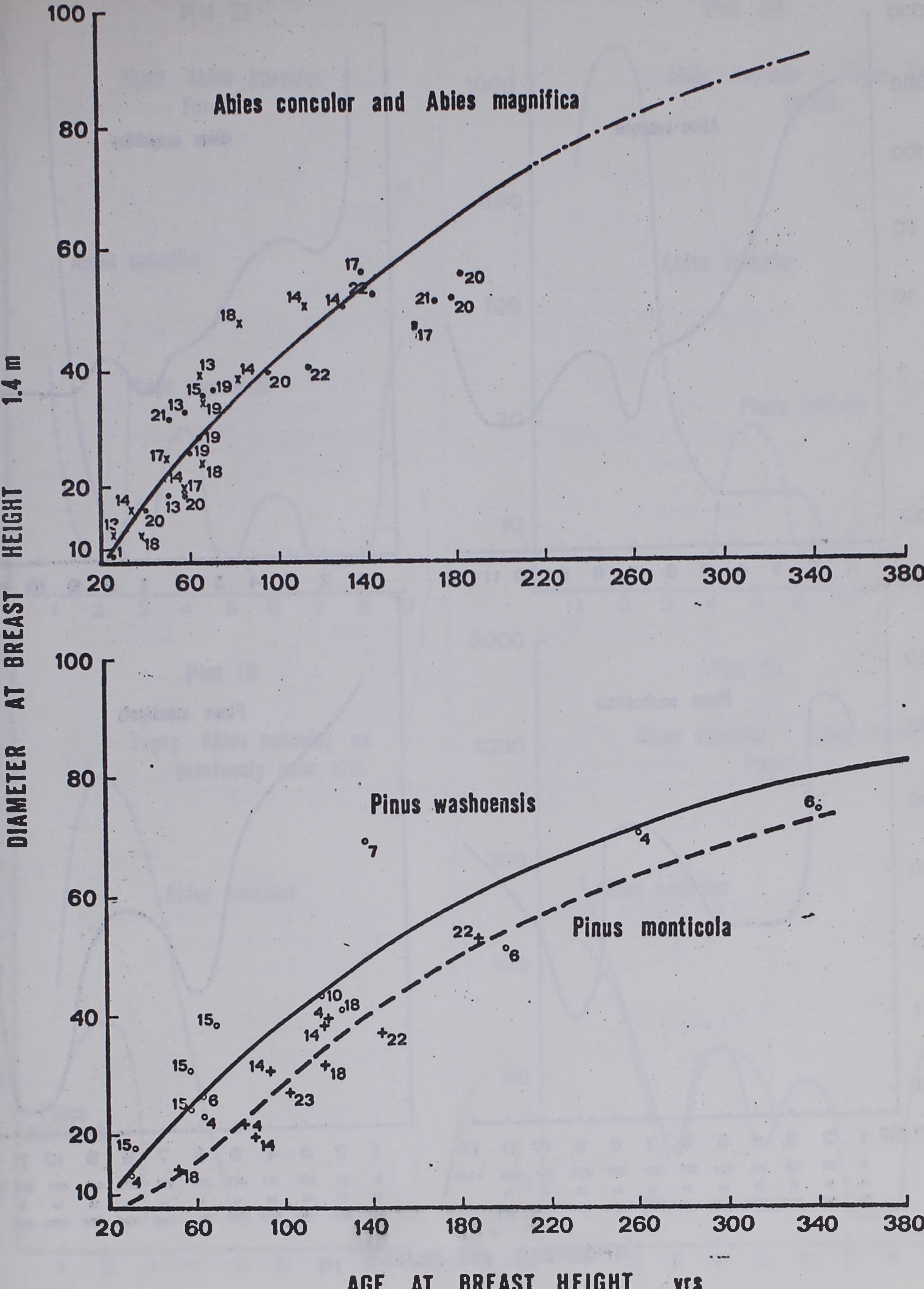
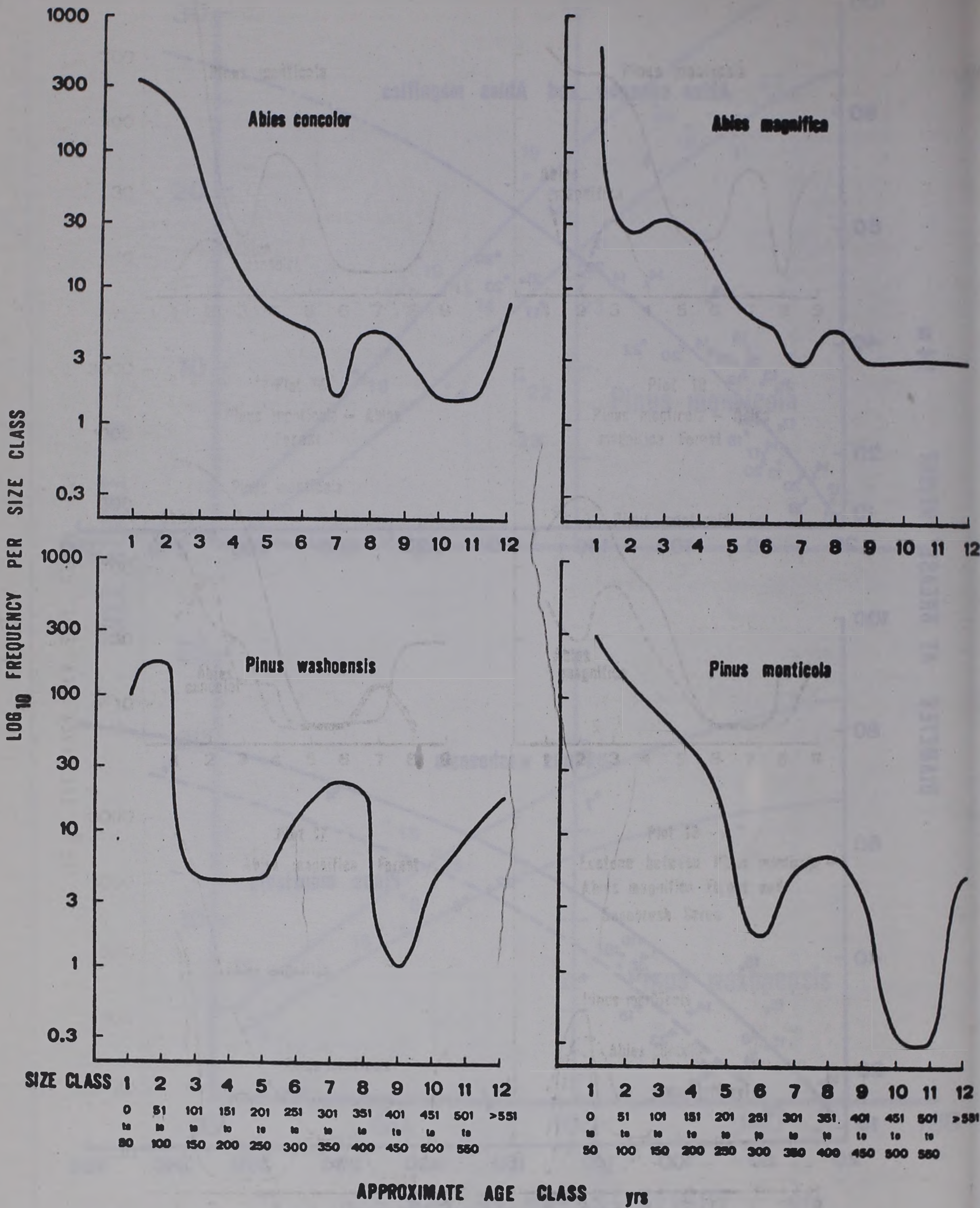

30
20
10
25
20
10
TREE HEIGHT m
Pinus monticola
Pinus washoensis
19
14
19
14
18
4
22
23
1
23
14
18
4
1
22
16
15
15
6
16
4
15
4
7
10
20
60
100
140
180
AGE AT BREAST HEIGHT yrs

Figure 7



Abies concolor and Abies magnifica
Pinus washoensis
Pinus monticola
DIAMETER AT BREAST HEIGHT 1.4 m
AGE AT BREAST HEIGHT .yrs.


Abies concolor
Abies magnifica
Pinus washoensis
Pinus monticola
LOG10 FREQUENCY PER SIZE CLASS
1000
300
100
30
10
3
1
0.3
SIZE CLASS 1 2 3 4 5 6 7 8 9 10 11 12
0 to 50
51 to 100
101 to 150
151 to 200
201 to 250
251 to 300
301 to 350
351 to 400
401 to 450
451 to 500
501 to 550
>551
APPROXIMATE AGE CLASS yrs

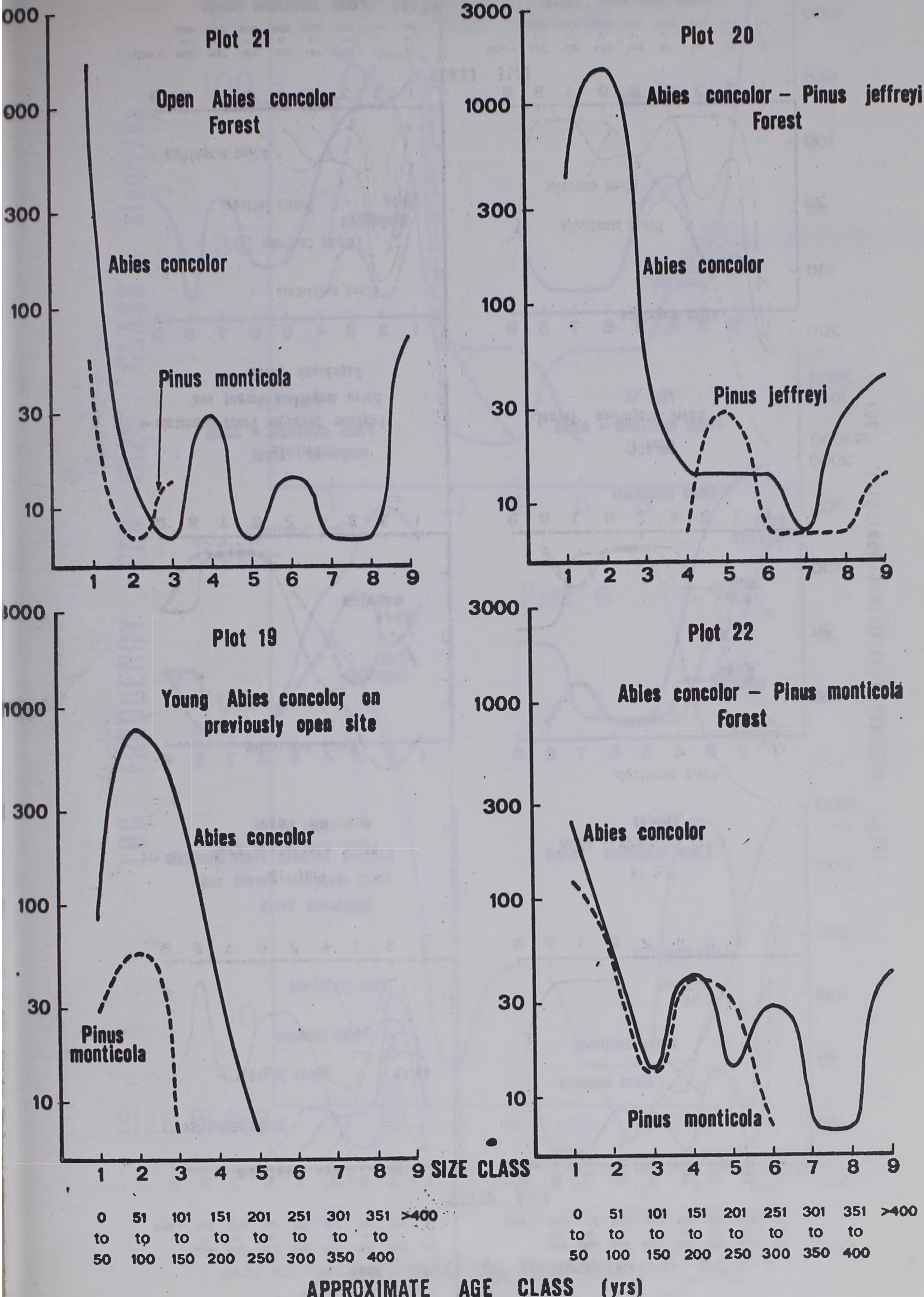
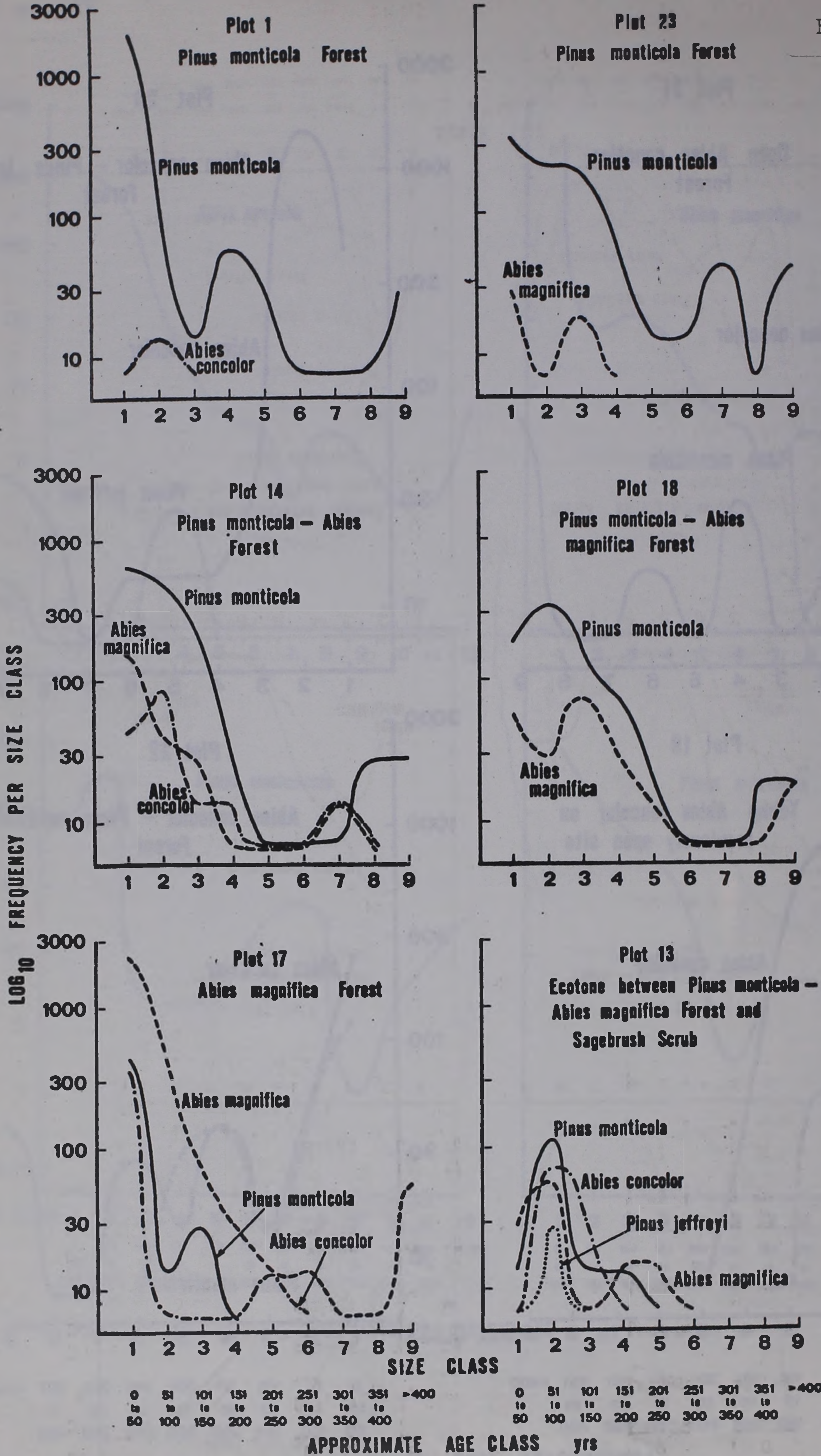

Plot 21
Open Abies concolor Forest
Abies concolor
Pinus monticola
Plot 20
Abies concolor – Pinus jeffreyi Forest
Abies concolor
Pinus jeffreyi
Plot 19
Young Abies concolor on previously open site
Abies concolor
Pinus monticola
Plot 22
Abies concolor – Pinus monticola Forest
Abies concolor
Pinus monticola
3000
1000
300
100
30
10
1 2 3 4 5 6 7 8 9 SIZE CLASS
0 to 50
51 to 100
101 to 150
151 to 200
201 to 250
251 to 300
301 to 350
351 to 400
>400
APPROXIMATE AGE CLASS (yrs)

Figure 10



Plot 1
Pinus monticola Forest
Pinus monticola
Abies concolor
Plot 23
Pinus monticola Forest
Pinus monticola
Abies magnifica
Plot 14
Pinus monticola — Abies Forest
Pinus monticola
Abies magnifica
Abies concolor
Plot 18
Pinus monticola — Abies magnifica Forest
Pinus monticola
Abies magnifica
Plot 17
Abies magnifica Forest
Abies magnifica
Pinus monticola
Abies concolor
Plot 13
Ecotone between Pinus monticola — Abies magnifica Forest and Sagebrush Scrub
Pinus monticola
Abies concolor
Pinus jeffreyi
Abies magnifica
LOG_{10} FREQUENCY PER SIZE CLASS
3000
1000
300
100
30
10
1 2 3 4 5 6 7 8 9
SIZE CLASS
0 to 50
51 to 100
101 to 150
151 to 200
201 to 250
251 to 300
301 to 350
351 to 400
>400
APPROXIMATE AGE CLASS yrs

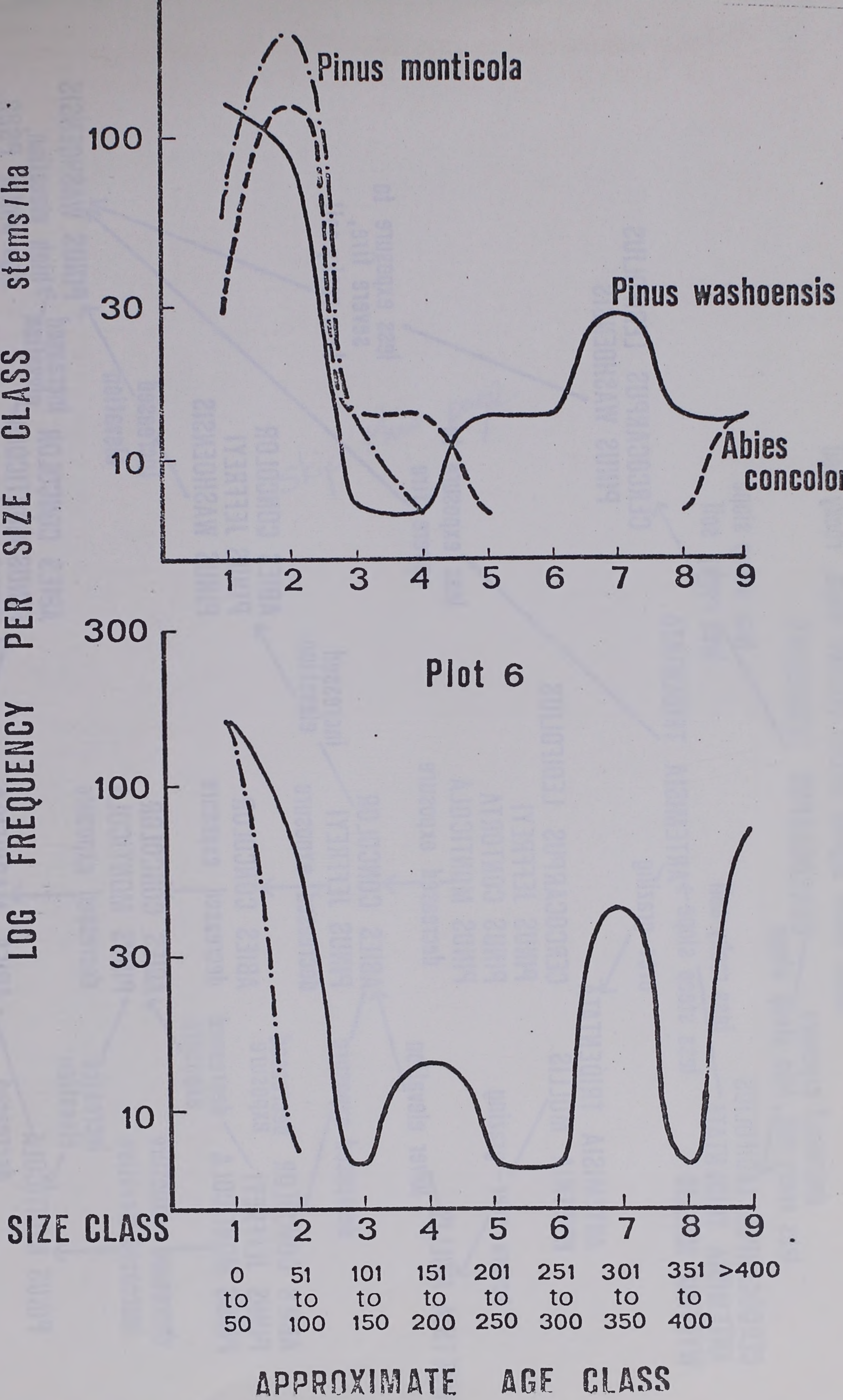
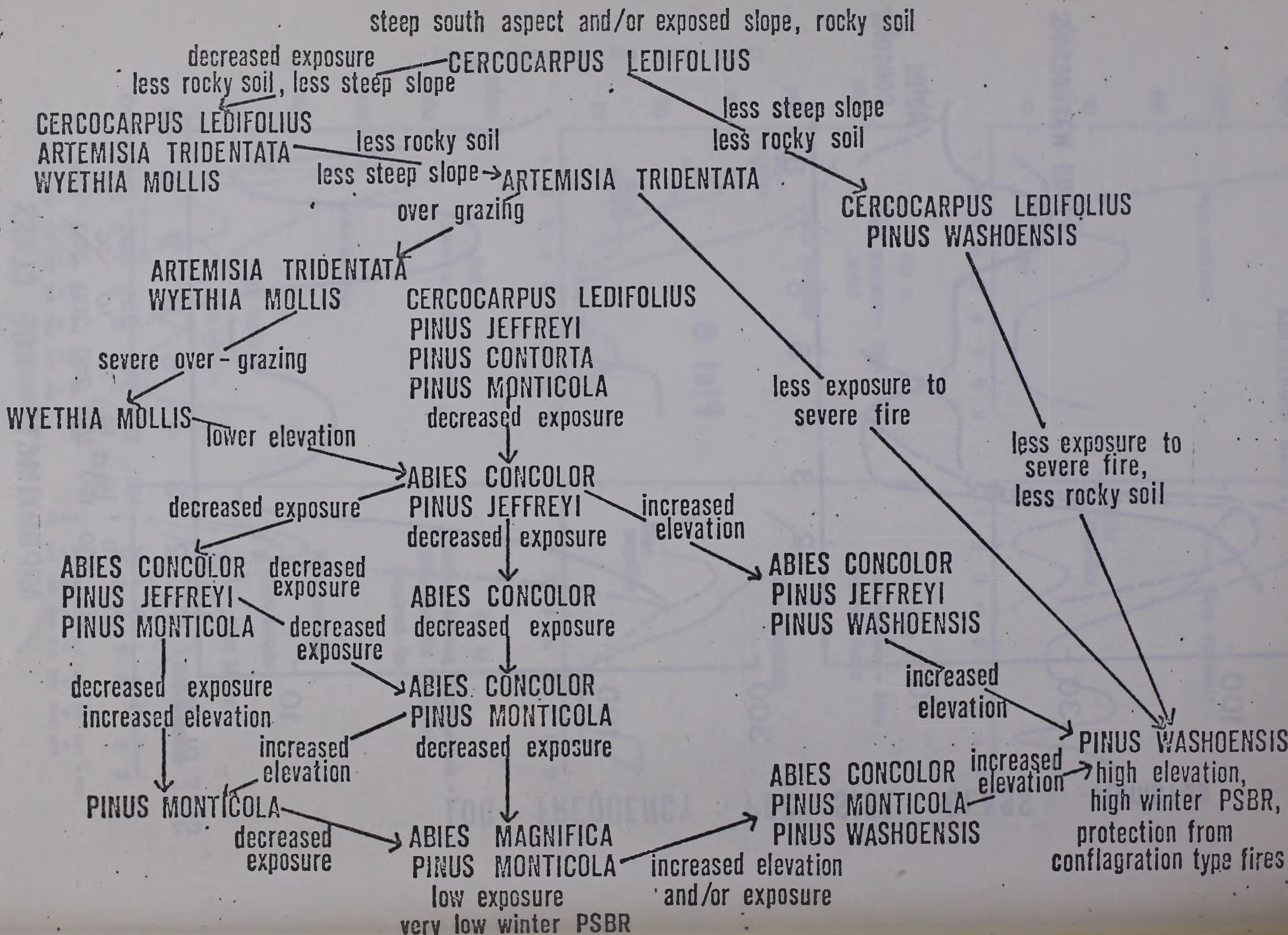

Pinus monticola
Pinus washoensis
Abies concolor
Plot 6
LOG FREQUENCY PER SIZE CLASS stems/ha
300
100
30
10
1
2
3
4
5
6
7
8
9
SIZE CLASS
0 to 50
51 to 100
101 to 150
151 to 200
201 to 250
251 to 300
301 to 350
351 to 400
>400
APPROXIMATE AGE CLASS

Figure 12


steep south aspect and/or exposed slope, rocky soil
CERCOCARPUS LEDIFOLIUS
decreased exposure
less rocky soil, less steep slope
CERCOCARPUS LEDIFOLIUS
ARTEMISIA TRIDENTATA
WYETHIA MOLLIS
less rocky soil
less steep slope
ARTEMISIA TRIDENTATA
less steep slope
less rocky soil
CERCOCARPUS LEDIFOLIUS
PINUS WASHOENSIS
over grazing
ARTEMISIA TRIDENTATA
WYETHIA MOLLIS
CERCOCARPUS LEDIFOLIUS
PINUS JEFFREYI
PINUS CONTORTA
PINUS MONTICOLA
severe over-grazing
less exposure to severe fire
WYETHIA MOLLIS
lower elevation
decreased exposure
less exposure to severe fire, less rocky soil
ABIES CONCOLOR
PINUS JEFFREYI
decreased exposure
increased elevation
decreased exposure
ABIES CONCOLOR
PINUS JEFFREYI
PINUS MONTICOLA
decreased exposure
decreased exposure
ABIES CONCOLOR
decreased exposure
ABIES CONCOLOR
PINUS JEFFREYI
PINUS WASHOENSIS
decreased exposure
increased elevation
ABIES CONCOLOR
PINUS MONTICOLA
increased elevation
increased elevation
decreased exposure
PINUS WASHOENSIS
high elevation,
high winter PSBR,
protection from
conflagration type fires
ABIES CONCOLOR
PINUS MONTICOLA
PINUS WASHOENSIS
increased elevation
PINUS MONTICOLA
decreased exposure
ABIES MAGNIFICA
PINUS MONTICOLA
low exposure
very low winter PSBR
increased elevation
and/or exposure